INSTRUCTION MANUAL
FOR THE
TELEMETERING SIGNAL GENERATOR
TYPE 202J

BOONTON RADIO COMPANY

Green Pond Road Rockaway, New Jersey

U.S.A.

2M/OBJ/3-63

Printed in U.S.A.

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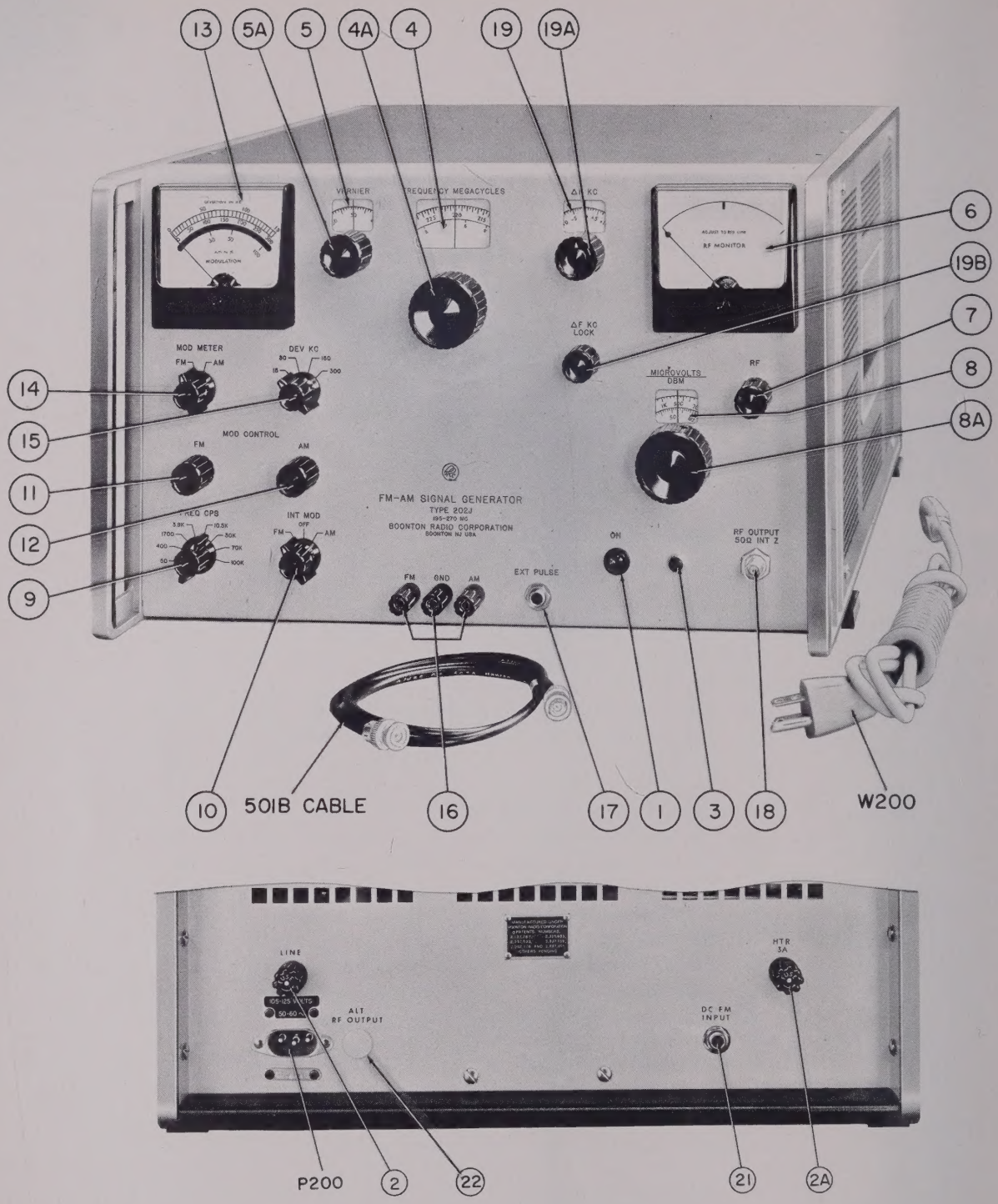


Figure 1. Operating Controls and Layout

1. Power Switch
2. Fuse (AC Line)
2A. Fuse (Filament)
3. Pilot Light
4. Main Frequency Dial
4A. Main Frequency Control
5. Vernier Frequency Dial
5A. Vernier Frequency Control
6. RF Monitor Meter
7. RF Control
8. RF Output Attenuator Dial
8A. RF Output Attenuator Control
9. Modulating Oscillator Frequency Selector
10. Internal Modulation Selector Switch
11. FM Deviation Control
12. Amplitude Modulation Control
13. Modulation Meter
14. Modulation Meter Switch
15. Deviation Range Switch
16. External Modulation Input Terminals
17. External Pulse Modulation Jack
18. RF Output Jack
19. Electronic Vernier Dial
19A. Electronic Vernier Control
19B. Electronic Vernier Dial Lock
21. DC FM Input
22. Alternate RF Output

SECTION I
DESCRIPTION

GENERAL

The type 202J Telemetering Signal Generator covers the frequency range from 195 to 270 mc and is designed for the measurement and calibration of FM telemetering receivers in the 215 to 260 mc band. The generator consists of a four-stage RF unit, together with a modulating oscillator and power supply, all housed in a single cabinet which may be readily adapted for rack mounting.

The RF unit consists of a variable frequency oscillator, a reactance tube modulator, a doubler, and an output doubler stage. The modulator is especially designed for maximum linearity and operates in conjunction with the electronic vernier to provide changes in RF output frequency as small as 10 cps with indications in 1 kc increments. The RF output is fed through a precision, variable attenuator; automatic RF level set is incorporated which maintains "red line" on the RF monitor meter over the entire band. The entire RF unit is shock mounted for minimum microphonism.

An internal audio oscillator provides a choice of eight frequencies which may be used for either frequency or amplitude modulation. A modulation meter indicates either FM deviation or % AM. However, the meter responds to the peak-to-peak value. The FM modulating system provides a bandwidth of 1 mc.

A completely solid-state power supply furnishes all necessary operating voltages.

OPERATING CONTROLS AND LAYOUT

A front and rear view of the instrument with all of its controls is shown in Fig. 1. All of the controls for operation of the 202J are located on the front panel. Instrument front panel designations are shown within quotation marks.

1. Power Switch

This switch applies power to the circuits when in the "ON" position.

2. Fuse (AC LINE)

This fuse in the ac line is located on the back panel of the instrument (3 amp. for 115 v input, 1½ amp. for 230 v input).

2A. Fuse (Filament)

This fuse (3 amp.) in the dc filament line is located on the back panel of the instrument.

3. Pilot Light

4. Main Frequency Dial "FREQUENCY MEGACYCLES"

The Main Frequency Dial is calibrated from 195 to 270 mc. A secondary or logging scale is divided into 24 equal parts for use with the Vernier Frequency Dial (5).

4A. Main Frequency Control

The Main Frequency control operates the Main Frequency Dial (4).

5. Vernier Frequency Dial "VERNIER"

This dial is divided into 100 divisions and is coupled to the Main Frequency Dial through a 24:1 gear train, providing a total of approximately 2200 logging divisions over the tuning range. A logging curve is shown in Fig. 2.

5A. Vernier Frequency Control

The Vernier Frequency Control operates the Vernier Frequency Dial (5) and the Main Frequency Dial (4).

6. RF Monitor Meter "RF MONITOR"

The RF Monitor Meter is used to standardize the input power level to the attenuator. In operation, the meter pointer is set to the center of the red calibration line on the meter scale.

7. RF Control "RF"

This adjustment sets the RF Monitor Meter (6) to the proper reference level such that the output attenuator calibration is direct reading.

8. RF Output Attenuator Dial "MICROVOLTS/DBM"

The RF Output Attenuator Dial is calibrated directly in (a) microvolts and (b) decibels below 1 milliwatt output to a 50 ohm load. It is standardized by setting the pointer of the RF Monitor Meter (6) to the center of the red calibration mark on the meter scale.

8A. RF Output Attenuator Control

The RF Output Attenuator Control operates the RF Output Attenuator Dial (8).

9. Modulating Oscillator Frequency Selector "FREQ CPS"

This control selects any one of eight fixed audio frequencies between 50 cps and 100 kc for either frequency or amplitude modulation.

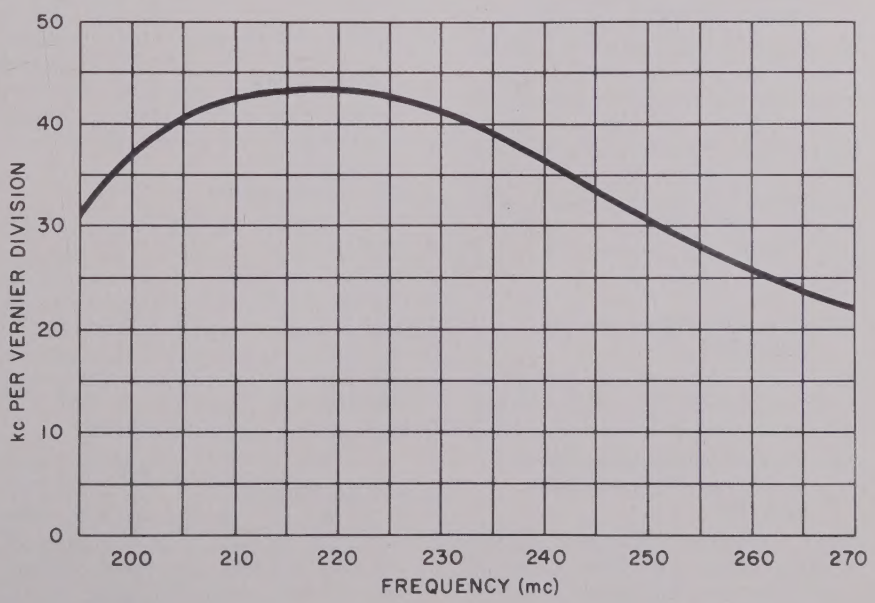


Figure 2. Logging Curve

10. Internal Modulation Selector Switch "INT MOD"

This switch connects the internal modulating oscillator for either frequency modulation or amplitude modulation. The OFF position disables the oscillator, but the panel terminals are connected, permitting external AM and FM.

11. FM Deviation Control "MOD CONTROL—FM"

A continuously variable control for adjusting the frequency deviation on any of the four ranges: 0-15 kc, 0-30 kc, 0-150 kc, 0-300 kc, for internal or external modulation source.

12. Amplitude Modulation Control "MOD CONTROL—AM"

A continuously variable control for adjusting the amplitude modulation level when either the internal AF oscillator or an external source is used.

13. Modulation Meter "MODULATION"

The Modulation Meter has three scales providing four FM deviation ranges and one amplitude modulation range: 0-150 kc deviation in 5 kc increments; 0 to 15 kc deviation in .5 kc increments; 0-300 kc deviation in 10 kc increments; 0-30 kc in 1 kc increments; and 0-100% amplitude modulation with calibration marks at 30%, 50%, and 100%. The 100% mark is for use only when an external modulating oscillator is employed.

14. Modulation Meter Switch "MOD METER"

By means of this control the Modulation Meter (13) may be switched to either the FM or AM modulating system to indicate the degree of modulation present. The FM and AM (up to 50%) positions are for use with either internal or external modulating oscillator. The AM 100% mark is for use only when an external modulating oscillator is employed.

15. Deviation Range Switch "DEV KC"

This rotary type switch selects four modulation meter FM deviation ranges: 0-15 kc, 0-30 kc, 0-150 kc, and 0-300 kc.

16. External Modulation Input Terminals "FM GND AM—EXT OSC"

These terminals provide a means whereby an external source of modulating voltage may be applied to the instrument. The output voltage of the internal oscillator is available at the external modulation input terminals for synchronizing or other purposes.

17. External Pulse Modulation Jack "EXT PULSE"

The Pulse Modulation Jack is provided to permit direct connection of an external modulation voltage source to the screen of the final stage for pulse or square wave modulation. When this connection is made the internal circuits are disconnected from the screen element.

18. RF Output Jack "RF OUTPUT 50Ω INT Z"

This BNC Type connector makes the generator RF signal available for use.

19. Electronic Vernier Dial "△F KC"

The Electronic Vernier Dial is calibrated to ± 30 kc for electronically shifting the output frequency in small increments. The total range of the control associated with this dial is ± 40 kc minimum. The Electronic Vernier Control knob (19A) is set for the electrical center of the control when the arrow points toward the top of the instrument (vertical). For best FM linearity, the knob arrow should be approximately vertical.

19A. Electronic Vernier Control

The Electronic Vernier Control operates the Electronic Vernier Dial (19).

19B. Electronic Vernier Dial Lock "△F KC LOCK"

The Electronic Vernier Dial Lock is used to mechanically zero the Electronic Vernier Dial (19). The dial is set to a desired reference indication and then locked while the Electronic Vernier Control is set for the desired reference frequency.

21. DC FM INPUT

The DC FM INPUT is located on the back panel of the 202J. This jack may be used to introduce an external dc voltage to control the output frequency over a limited range. Typically, the sensitivity is approximately 120 kc per volt dc. Refer to Section V — Operational Guide for additional information.

22. ALT RF OUTPUT OR HIGH LEVEL OUTPUT (Optional)

The RF OUTPUT CONNECTOR (18) may be removed from the front panel and inserted in the hole provided on the rear panel. This hole is covered by an easily removable plug button. This plug button is used to cover the front panel hole when the Output Connector is placed on the rear panel. In the Model 202JA, this hole is used to accommodate the high level output jack. For changing the RF output from front panel to rear in these models, a 523A adapter must be used for rack mounting.

SECTION II
SPECIFICATIONS

Radio Frequency Characteristics

RF RANGE:
195-270 MC

RF ACCURACY:
Main Dial: ±0.5%*
Electronic Vernier: ± (10% + 1 KC)*
*after one hour warm-up

RF CALIBRATION
Main Dial: Increments of 0.5 MC
Mechanical Vernier: 2200 divisions through range
Electronic Vernier: Increments of 1 KC over ±30 KC range*
*total range ±40 KC; provision for slipping dial to place "0" at a specific frequency

RF STABILITY:
< 0.02% per hour*
*after two hour warm-up

RF OUTPUT:
Range: 0.1 μv to 0.2 volts*
*across external 50 ohm load at panel jack
Accuracy: ±10%, 0.1 μv to 50 K μv
±20%, 50 K μv to 0.2 volts
Auto Level Set: holds RF monitor meter to "red line" over band
Impedance: 50 ohms
VSWR: < 1.2
Spurious Output: All spurious RF output voltages are at least 25 db below desired fundamental

RF LEAKAGE:
RF Leakage: Sufficiently low to permit measurements at 0.1 μv

Amplitude Modulation Characteristics

AM RANGE:
Internal: 0-50%
External: 0-100%

AM ACCURACY:
±10% at 30% and 50% AM

AM CALIBRATION:
30, 50, 100%

AM DISTORTION:
< 5% at 30%
< 8% at 50%
< 20% at 100%

AM FIDELITY:
±1 db, 30 cps to 200 KC

EXTERNAL AM REQUIREMENTS:
Approx. 50 volts RMS into 7500 ohms for 100% AM

Frequency Modulation Characteristics

FM DEVIATION RANGE:
Internal: 0-300 KC in 4 ranges
External: 0-300 KC in 4 ranges

FM DEVIATION ACCURACY:
±5% of full-scale*
*indication proportional to peak-to-peak modulating waveform

FM CALIBRATION:
0-15 KC in increments of 0.5 KC
0-30 KC in increments of 1 KC
0-150 KC in increments of 5 KC
0-300 KC in increments of 10 KC

FM NON-LINEARITY*:
< 1.5% at 150 KC
< 5% at 300 KC
*"least squares" departure from straight line passing through origin

FM BANDWIDTH:
±3 db, 3 cps to 1 MC

FM FIDELITY (MODULATION RATE)
±1 db, 5 cps to 500 KC

SPURIOUS FM:
Total RMS spurious FM from 60 cps power source is at least 60 db below 150 KC

MICROPHONISM:
Extremely low; shock-mounted RF unit

EXTERNAL FM REQUIREMENTS:
< 1 volt RMS into 100K ohms for 150 KC deviation

Pulse Modulation Characteristics

PM SOURCE: External

PM RISE TIME: < 0.25 μsec

PM FALL TIME: < 0.8 μsec

Modulation Oscillator Characteristics

OSC FREQUENCY:

OSC Frequency:		
	50 cps	10.5 KC
	400 cps	30 KC
	1700 cps	70 KC
	3900 cps	100 KC

OSC ACCURACY: ±5%

OSC DISTORTION: < 0.5%

OSC EXTERNAL OUTPUT:
20 volts approx. at external FM posts
30 volts approx. at external AM posts

Accessories

FURNISHED:
Type 502-B Patching Cable

AVAILABLE:
Type 207-H Univerter
Type 501-B Output Cable
Type 504-A Adapter
Type 505-B Attenuator
Type 506-B Patching Cable
Type 507-B Adapter
Type 508-B Adapter
Type 509-B Attenuator
Type 510-B Attenuator
Type 514-B Output Cable
Type 517-B Output Cable
Type 523-A Adapter

Tube Complement

TUBES	TRANSISTORS	DIODES
3 — 6688	1 — 2N1533	2 — IN660
1 — 6AF4A	1 — 2N1136	4 — 1N1763
1 — 6AW8A	3 — 2N1379	4 — 1N1764
3 — 6AU6A		2 — 1N1581
1 — 6BK7A		1 — S1029
1 — 6AQ5A		1 — 1N34A
1 — 12AU7A		
1 — 6DJ8		

Physical Characteristics

MOUNTING:

Cabinet for bench use; readily adaptable for 19" rack mounting

FINISH:

Gray engraved panel; green cabinet (other finishes available on special order)

DIMENSIONS: (see Fig. 3)

WEIGHT:

Net:	45 lbs.	Gross Export:	100 lbs.
Gross Domestic:	60 lbs.	Legal Export:	55 lbs.

Power Requirements

202-J: 105-125/210-250 volts, 50-60 cps, 100 watts

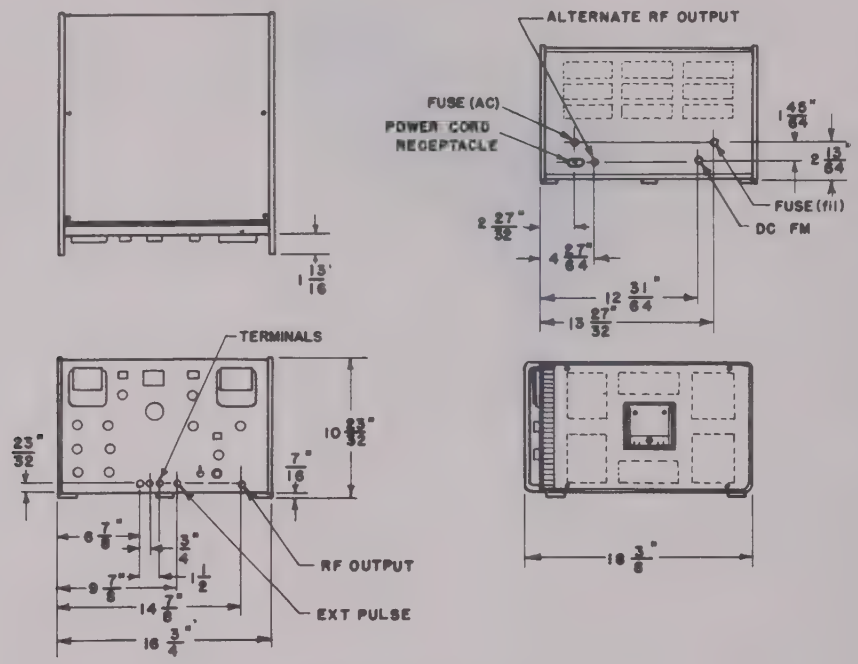


Figure 3. 202J Dimensions

SECTION III
OPERATING INSTRUCTIONS

INSTALLATION

Remove the type 202J Signal Generator from its shipping carton and place it in position on a test bench. If the instrument is to be mounted in a rack, refer to Fig. 4 for mounting the accessory hardware.

CAUTION: Shipping support screws[1] should be disengaged before operation of the 202J Signal Generator. Use the procedure given below.

Removal of Shipping Support Screws

1. Remove top cover of the instrument.
2. Disengage the four shipping support screws (Fig. 5) by turning the screws clockwise until the washers lock on the threaded hexagonal spacer. Use a #8 (5/64") hex wrench. The RF Unit should float freely.
3. Replace top cover of the instrument.

SECURE RF UNIT WITH DEVICES PROVIDED WHENEVER SHIPPING THE 202J.

Connect the power cord to the power socket at the rear of the 202J. Then connect the power cord to a 105-125v, 50 or 60 cps source. An input voltage switch is on the chassis at the right rear of the instrument and may be operated to use the 202J with a 210-250v, 50 or 60 cps source. (This switch is accessible only after removal of the top cover.)

NOTE: Reverse voltage plate on back panel to agree with switch and change fuse as described under "2. Fuse (AC Line)"

Set the power switch to the "ON" position and allow unit to warm up a minimum of two hours for stabilized output frequency. However, all other operations will be normal after a fifteen minute warm up.

1—In instruments with serial numbers up to 5682, wooden shipping blocks are used. Blocks may be removed after removal of shipping screws as indicated in Fig. 5.

INSTRUCTIONS
1. REMOVE TILT STAND, FEET, AND PLASTIC TRIM.
2. ATTACH TRIM STRIP AND FLANGES, KEEPING LARGE NOTCH ON FLANGE TO INSTRUMENT BOTTOM.

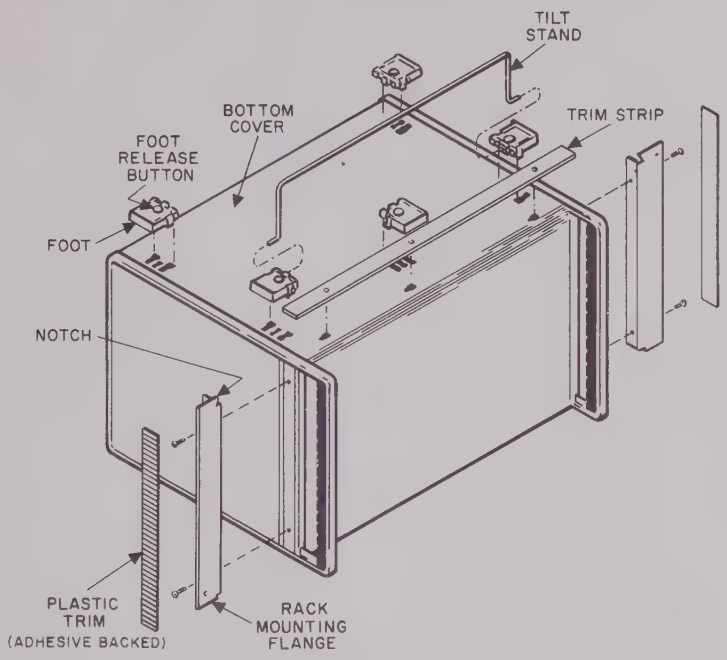


Figure 4. Rack Mounting Instructions

PRELIMINARY INSTRUCTIONS

(See Fig. 1)

Operation of the RF control (7) should cause the pointer of the RF Monitor Meter (6) to move. After initial adjustment, the meter should remain within the red line reference mark over the entire 195 to 270 mc range of the instrument. This is an indication that the RF oscillator, RF Amplifiers, and AGC Amplifiers are working properly.

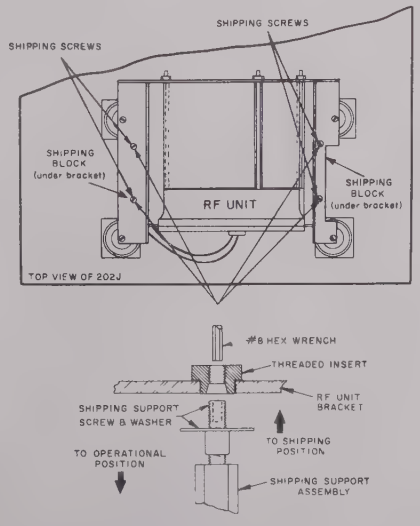


Figure 5. Shipping Supports

To check the FM and AM modulation systems, turn the Internal Modulation Selector Switch (10) to "FM", the Modulation Meter Switch (14) to "FM" and the Deviation Range Switch (15) to 15 kc, 30 kc, 150 kc, or 300 kc. Operating the FM Deviation Control (11) in a clockwise direction should cause the Modulation Meter (13) to read increasing deviation. Switch the Modulation Selector Switch (10) to "AM", the Modulation Meter Switch (14) to "AM"; rotate the Amplitude Modulation Control (12) clockwise. The Modulation Meter (13) should read the per cent of amplitude modulation present and should be capable of reaching 50%. (100% AM is only specified when using an external source of modulating frequency.) Momentary rapid fluctuation of the modulation meter pointer, when either the Modulation Selector Switch or Modulation Meter Switch is thrown, is normal and does not overload the meter.

USING THE SIGNAL GENERATOR

Frequency Modulation

Four frequency deviation ranges 0-15 kc, 0-30 kc, 0-150 kc, and 0-300 kc are provided, each continuously adjustable. Calibrated increments are .5 kc on the 15 kc range, 1 kc on the 30 kc range, 5 kc on the 150 kc range, and 10 kc on the 300 kc range. With an external modulation source, less than 1 volt rms into 100 K ohms is required for 150 kc deviation with the FM Deviation Control maximum clockwise.

Amplitude Modulation

0-50% Modulation: Utilizing the internal audio oscillator or an external modulating oscillator, amplitude modulation may be obtained over the range of 0-50% with meter calibration points provided at 30% and 50% modulation points.

0-100% Modulation: Using an external modulating oscillator capable of 50 volts rms into 6000 ohms, the RF carrier may be amplitude modulated to 100%. For this purpose, the modulation meter has a scale calibration point at 100%.

Pulse Modulation: A front panel jack is provided which permits direct connection of an external modulation voltage source to the screen of the final stage for pulse or square wave modulation. When this connection is made, internal circuits are disconnected from the screen element. Approximately 30 vdc are required to maintain the carrier at its normal level. Application of approximately —7.5 volts will give maximum ON-OFF ratio. The 7.5 v negative swing can be achieved by a small dc supply in series with the pulse source, or by ac coupling a pulse with a suitable duty cycle. Under these conditions the ON-OFF ratio exceeds 30 db. (See Figure 6.)

In order that the attenuator system may accurately indicate the rms output voltage at pulse peak, it is necessary to equate the positive pulse amplitude to the dc screen voltage at the particular carrier frequency of interest. This can be done with a good direct coupled oscilloscope (bandwidth determined by type of pulse employed). With the oscilloscope on 5v/cm, connect it to the tip of the "Ext. Pulse" jack without breaking the internal contact. The oscilloscope will then read the dc final amplifier screen voltage (typically 20-40 vdc). Then, connect the pulse source (disconnecting the internal circuit) and set its positive amplitude to the same voltage as above.

Simultaneous Modulation

For certain tests, simultaneous FM and AM is sometimes desired. The 202J Telemetering Signal Generator, in combination with an external low distortion modulating oscillator, may be used for this purpose, provided that the modulating oscillator is capable of developing approximately 2 volts rms across a 100 K ohm load; the FM requirement for 300 kc deviation.

In use, the external modulating oscillator is connected to the FM external Modulation Input Terminals (16), the Internal Modulation Selector Switch (10) set to AM, and the levels of each type of modulation independently set on the Modulation Meter (13) by operation of the Modulation Meter Switch (14), FM Deviation Control (11), and Amplitude Modulation Control (12). For maximum accuracy, the % AM should be set first with the external FM source off, since the % AM meter will read the small residual AM caused by high deviation FM.

CAUTION: Use of an external audio oscillator for AM, with the INTERNAL MODULATION OSCILLATOR switched to FM, will result in interaction between modulation circuits when both oscillators are operating at or near the same audio frequency.

Simultaneous FM at two modulation frequencies or simultaneous AM at two modulation frequencies is also possible when two external oscillators are used. In practice, the external modulating oscillators are connected to the pair of External Modulation Input Terminals (16), which are marked, and the Modulation Selector Switch is set to OFF.

OUTPUT CONNECTIONS

The method of connecting the load to the 202J Signal Generator must be considered to insure proper interpretation of results, and the following discussion is offered as an aid to the user.

It is convenient to represent a signal source in terms of its open circuit voltage and internal impedance. Thus, a signal source or an antenna can be represented as in Fig. 7. For simplicity, only the case where source and load impedance are resistive will be considered. This represents the output connections when the Type 502B cable is used.

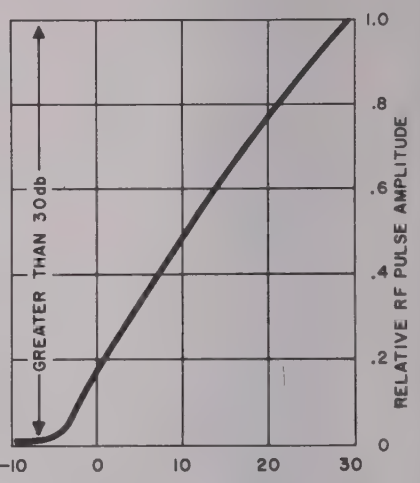


Figure 6. 202J Pulse Modulation Characteristics

For purposes of rating sensitivity, the input to a receiver might have been defined initially either as the open circuit source voltage 2E or the voltage actually across the receiver terminals. The Institute of Radio Engineers has established the former method as standard and defined receiver input in terms of the open circuit voltage of the source.[1]

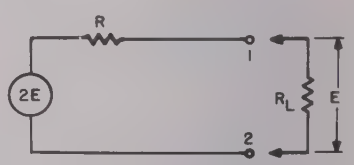


Figure 7. Signal Source Representation

The impedance of the signal source employed to test receivers should be equal to the impedance of the antenna with which the receiver is designed to operate. Note that in this case the voltage actually across the receiver terminals is $\frac{2E}{2} = E$ (Receiver input impedance equal to source impedance).

1—IRE STD 17.S1 Standards on Radio Receivers: Methods of Testing Frequency Modulation Broadcast Receivers, 1947. Adopted by ASA.

IRE STD 17.S1 Standards on Radio Receivers: Methods of Testing Amplitude-Modulation Broadcast Receivers, 1948. Adopted by ASA.

IRE STD 17.S1 Standards on Television: Methods of Testing Monochrome Television Broadcast Receivers, 1960. Adopted by ASA.

The 202J signal generator is calibrated to read the voltage "E" of Figs. 7 through 11.

Accessories for physically connecting the instrument to the load are described in the following:

502B Patching Cable

Provides simple connection for a matched load. (See Fig. 7.)

501B Output Cable

The 501B Cable attached to the 202J is illustrated by Fig. 8, where R_2 is the 50-ohm termination of the 501B Cable.

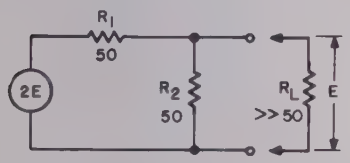


Figure 8. Output Circuit of 202J with 501B Output Cable Attached

The equivalent circuit (Fig. 9) is readily determined by applying Thevinin's theorem. This arrangement is recommended for general use where it is desirable to connect the 202J output to an input circuit of much higher impedance than 50 ohms. The attenuator of the 202J will read the open-circuit output directly.

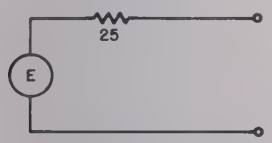


Figure 9. Equivalent Output Circuit of 202J with 501B Output Cable Attached

505B 6 db Pad

This pad is used as a dummy antenna in testing unbalanced receivers with a 50-ohm input as shown in Fig. 10.

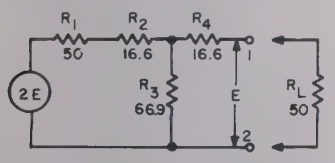


Figure 10. 505B T-Pad (Attenuator) Circuit

The open-circuit voltage appearing across terminals 1 and 2 is by Ohms law equal to E, half of the source voltage. Applying Thevinin's theorem, the equivalent circuit of Fig. 11 is obtained, and thus the attenuator dial of the 202J

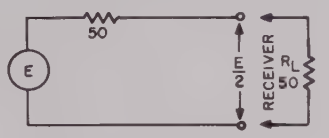


Figure 11. 505B T-Pad (Attenuator) Equivalent Circuit

reads receiver sensitivity directly for the assumed standard output. This circuit is well matched and the 202J attenuator reads the open circuit source voltage as specified in footnote 1 for receiver sensitivity measurement.

509B 20 db T-Pad

The 509B pad, like the 505B, may be used as a dummy antenna, except that the open circuit voltage, which is a measure of receiver sensitivity (equivalent source voltage), is one-fifth the 202J attenuator dial reading. The source impedance is 50 ohms.

SECTION IV
THEORY OF OPERATION

GENERAL

The 202J Telemetering Signal Generator is shown in block diagram form in Fig. 12. This instrument is designed for use in the field of telemetry and associated equipment in the frequency range of 195 to 270 mc. The bandwidth and modulation linearity will simulate a telemetering signal using FM, AM, or pulse modulation.

The generator consists of an RF Unit, which is the radio frequency generating portion of the instrument; modulation circuitry; an output monitoring system; an internal modulating oscillator; and a power supply.

RF UNIT

The RF Unit is a four-stage frequency generating sub-assembly. It contains an RF oscillator, 1st frequency doubler, 2nd frequency doubler, and reactance modulator.

The RF oscillator V101 (6AF4) is a tuned plate oscillator covering the range of frequencies from 48.75 mc to 67.5 mc, inclusive. Tuning is accomplished by means of C109 which is part of the ganged tuning capacitor also including C101, C115, and C123. (See Fig. 68.)

The first frequency doubler V102 (6688) has an output range of 97.5 mc to 135 mc, inclusive. This stage also acts as a buffer to isolate the frequency source from the output. The high gain of this stage permits a high level driving voltage to be delivered to the output stage. The combination of saturation of the output tube and the limiting action of the input to the output stage removes much spurious amplitude modulation.

The second frequency doubler V103 (6688) is also the AM modulator. The frequency range of this stage is 195 mc to 270 mc, inclusive.

The reactance modulator V100 (6688) or frequency modulator is actually an inductive element across the tuning tank of the RF oscillator (V101). In order to maintain constant frequency deviation sensitivity over the entire tuning range of the instrument, the amount of inductance produced by V100 is made to vary directly as the carrier frequency. This is accomplished by the proper attenuation characteristic of a bridged-tee 90° phase shift network consisting primarily of R101, C101, R100 and C_{gp}, with associated circuitry as shown in Fig. 13. Although

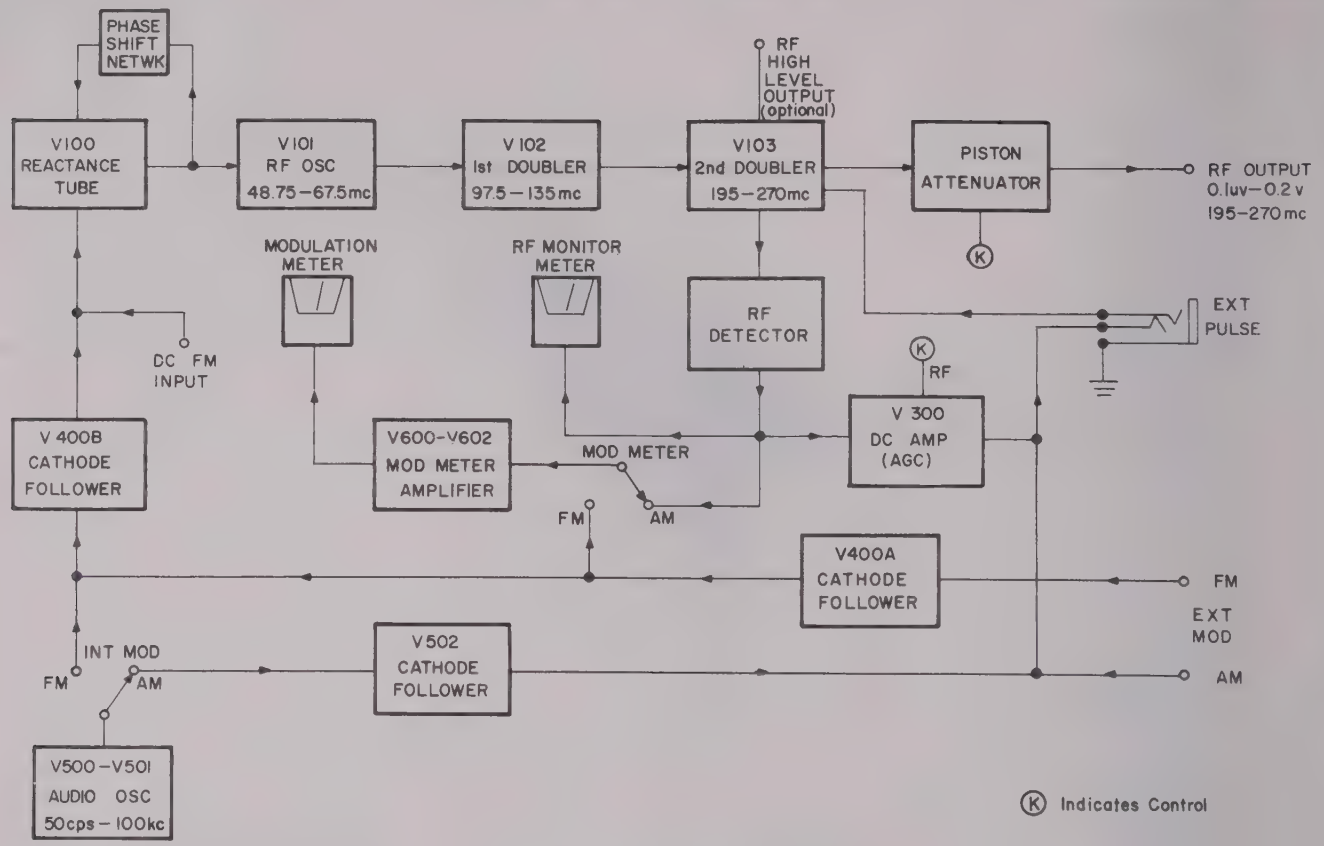


Figure 12. 202J Block Diagram

this circuit arrangement is capable of producing fairly constant deviation with fixed components, C101 is made variable and ganged with the oscillator tuning capacitor to provide the constancy of frequency deviation required in a precision signal generator.

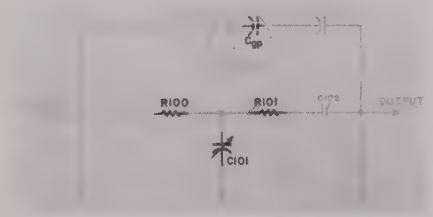


Figure 13. Bridged-Tee Phase Shift Network

Fixed bias is supplied through variable resistor R107 to establish the operating point of V100. RF signals are bypassed at the cathode by C126. Additional modulation frequency gain stability, by means of negative current feedback, is achieved by the small value of bypass capacitor C126.

For FM, V100 is modulated by applying the modulating voltage to the grid of the tube through Section 4 of the RF filter (307964), which prevents RF energy from leaking out of the instrument.

For AM, V103 is modulated by applying the modulating voltage to the screen grid of the tube. The screen dc voltage is supplied from the AGC amplifier.

For pulse modulation, the screen grid of V103 is modulated as with AM, except that no internal voltages are supplied to the screen grid, so all voltages must be supplied through the EXT PULSE jack on the front panel of the instrument.

A piston type RF attenuator is inductively coupled to the tank coil of the modulator by means of a single loop of wire in the same plane as the loop of the tank coil. A 50-ohm carbon film resistor in series with the loop provides a 50-ohm source impedance. At the point where the loop connects to the output coaxial cable there is an impedance compensating circuit composed of a 50-ohm resistor and a capacitor in series to ground (Fig. 14). The circuit tends to draw current of a leading phase when the loop phase is lagging, resulting in the maintenance of good low VSWR source impedance from the attenuator output.

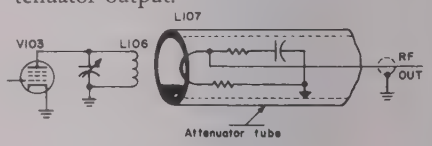


Figure 14. Piston Attenuator Circuit

The pickup loop of the attenuator is continuously adjustable along the axis of the attenuator tube by means of a rack and pinion drive.

The Transverse Electric (TE_{11}) wave amplitude is held constant by the AGC circuit and is logarithmically attenuated in the "waveguide-below-cutoff" attenuator tube.[1]

1—"Technique of Microwave Measurements," Vol. 11, Radiation Lab. Series, Chapt. 11, Page 686.

The attenuator dial is calibrated directly in microvolts and decibels below 1 milliwatt (dbm) across an EXTERNAL 50-ohm load. Thus, the dial is calibrated as "E" of Figs. 7 through 11. The output is standardized by setting the output monitor meter to "red line".

The attenuator can be represented by the equivalent Thevenin circuit where 2E varies logarithmically with the placement of the attenuator piston in the tube (Fig. 7).

MODULATION CIRCUITS

The FM circuit can be modulated by the internal oscillator or through the external modulation input terminals provided on the front panel of the instrument. The external source will be required to supply 1 volt rms to the 100 K input for 150 kc deviation with FM Deviation Control maximum clockwise. This external channel has a flat response, ± 1 db, from 5 cps to 500 kc.

The metering of the frequency modulation is accomplished by sampling the input voltage to the cathode follower which drives the reactance modulator. The diagram (Fig. 15) shows the frequency modulation and metering of the 202J.

The RF carrier can be amplitude modulated by the internal oscillator or through the external modulation input terminals provided on the front panel of the instrument. The external source will be required to supply approximately 50 volts rms into 6000 ohms for 100% AM. The AM channel has a flat response (±1 db, from 30 cps to 200 kc). For AM, the screen grid of the second doubler is modulated. Characteristically, screen grid modulation has two disadvantages; viz., the modulation response will not be absolutely linear and the screen grid offers a varying dynamic load impedance. The design of the 202J has overcome these two difficulties by: first, predistorting the input in the opposite direction to the distortion caused by the screen; and secondly, by driving the screen grid with a low impedance cathode follower. Fig. 16 shows in block diagram form the circuitry for amplitude modulating the 202J.

In contrast to the metering of the FM function, the AM is metered by sampling the modulated RF, detecting, and measuring the recovered signal. This is indicated in Fig. 16.

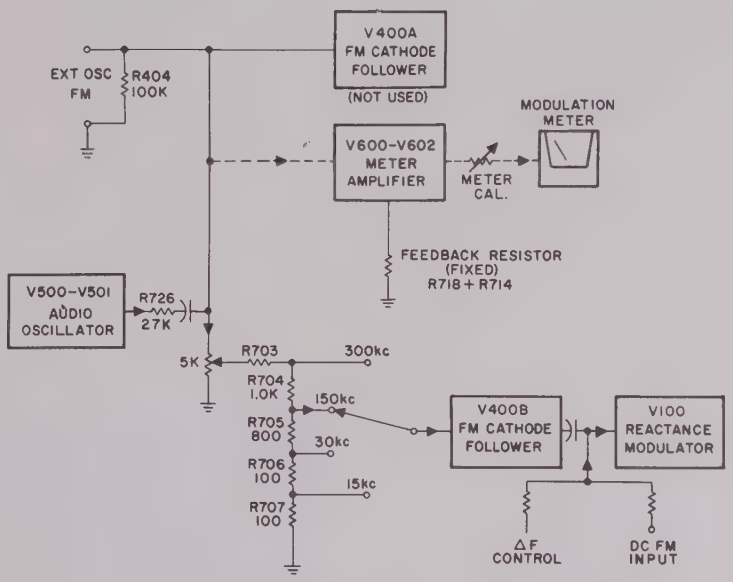


Figure 15A. Modulation & Metering — Internal — FM

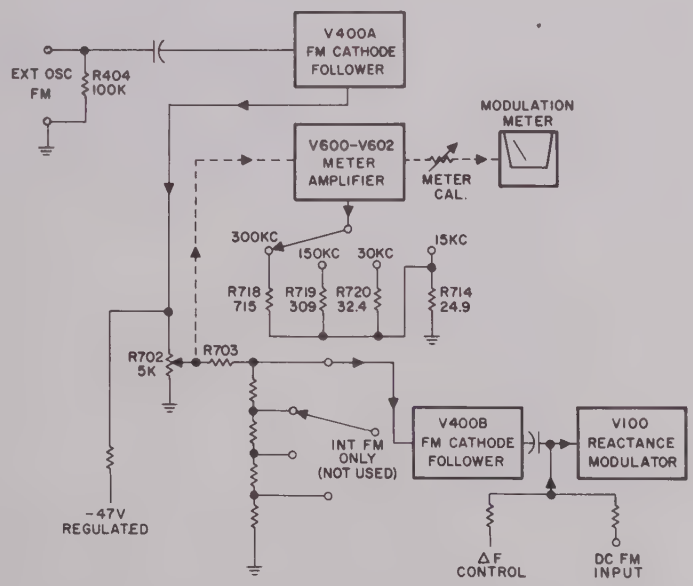


Figure 15B. Modulation & Metering — External — FM

Pulse modulation of the 202J is done at the same point as for AM, the screen grid of the output stage. When pulse modulating, which must be done from an external source, all internal circuits are disconnected from the screen grid of V103, including the automatic level setting circuitry. (See Fig. 17). When the external plug disconnects the internal circuitry, the screen grid voltage is determined by the external circuit. With zero volts at the screen grid, the output of the 202J will decrease at least 15 db below normal. The approximate range of control of the output tube by the screen grid is from 30 volts for full output to —7.5 volts for essentially cutoff condition. (See Fig. 6.) Inasmuch as the oscillator is still operating, there will be a small amount of RF leakage through the output tube interelectrode capacitance. In this cutoff condition the output signal will be approximately 30 db below normal. See Section III—Using the Signal Generator, Pulse Modulation.

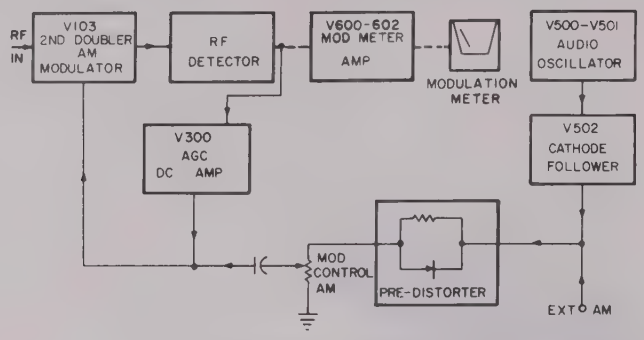


Figure 16. Modulation & Metering — AM

OUTPUT MONITOR SYSTEM (Fig. 18)

An RF detector (CR101) is connected to the output tube (V103) plate circuit. The modulated or unmodulated RF is sampled through the small capacitor C121. The RF signal is demodulated and the resulting signal is the modulating signal (if RF is modulated) plus a dc level, proportional to the RF amplitude. The modulation signal is coupled to the Modulation Meter circuitry through C600. The dc voltage is indicated on the Monitor Meter which is in the grid circuit of the AGC DC Amplifier (V300A). The triode section of V300 amplifies the difference between the DC potential out of diode CR101 and the triode cathode potential which is set by the panel "RF" control. The pentode section further amplifies this difference and applies the result to the screen of V103. As tracking, tuning, and tube aging vary the RF level, the amplified difference of the output of CR101 and the reference voltage adjusts the screen potential of V103 to correct for these effects.

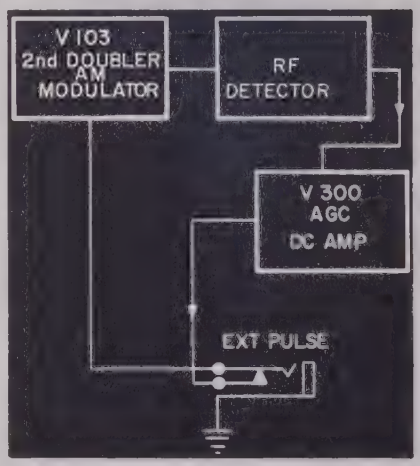


Figure 17. Modulation — Pulse

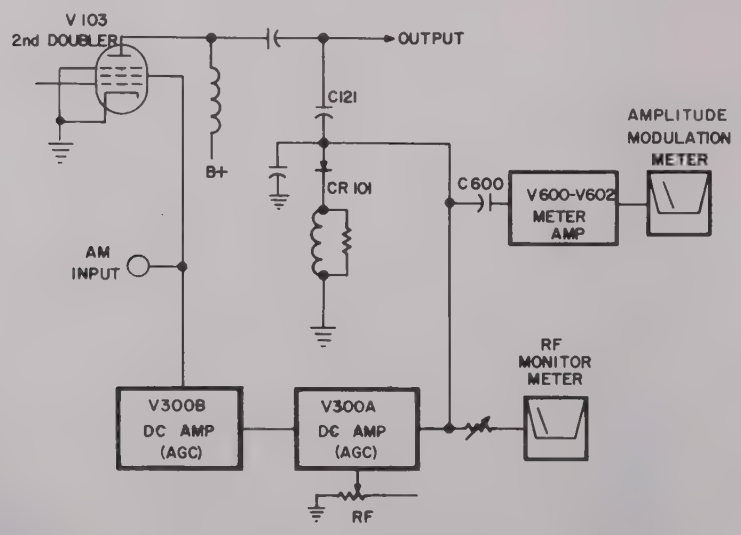


Figure 18. Output Monitor System

MODULATING OSCILLATOR

The AF oscillator employed is quite free of distortion, having, in general, total harmonic content of less than 0.5% internally.[1] The conventional Wein Bridge type R-C oscillator is used. Approximately 30 volts rms is available from the AM-External Modulation Input Terminals for oscilloscope synchronization or sweep. The output is controlled by adjustment of R510 which regulates the amount of negative feedback voltage applied to the cathode of V500.

The specific modulation frequencies supplied by the 202J internal audio oscillator were chosen because they are among the IRIG subcarrier frequencies used in Telemetry systems. The 50 cps and 100 kc frequencies, although not IRIG subcarriers, are to facilitate receiver fidelity measurements.

DC FM INPUT

The instantaneous voltage on the grid of the reactance modulator tube (V100) determines the instantaneous output frequency of the 202J. Referring to Fig. 19, it will be noted that either an ac voltage (by way of the cathode follower V400B) or a dc voltage (through the DC FM INPUT jack) can be supplied to the reactance modulator (V100). There are two sources of dc. First, is the small incremental frequency deviation voltage supplied by the △F KC control. Secondly, the external dc voltage can be supplied from an external AFC system or from an external frequency plotter system. The frequency sensitivity of the DC FM INPUT jack is approximately 1 volt dc for 120 kc deviation. The impedance is 22K ohms.

POWER SUPPLY

The 202J power supply utilizes solid-state components in the circuitry. Silicon diodes are used in the full-wave bridge rectifier and the dc filament supply. All regulation is done with semiconductors; i.e., transistors and zener diodes.

The +150 volt regulator is shown in Fig. 20. It is identical in principle to the conventional "series regulator" with voltage reference (CR210), feedback amplifier (Q202, Q203, and Q204) and series control element (Q201). Since Q201 is connected between the negative 100 volt input and ground,

1—See Section VI — Maintenance, for Harmonic Distortion measurement.

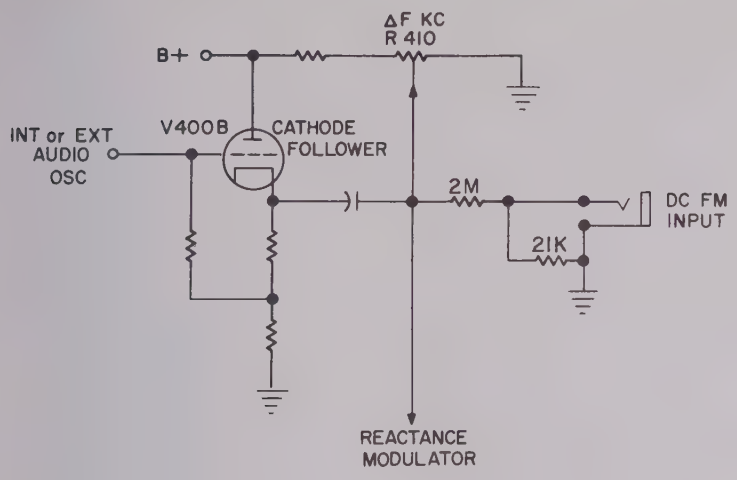


Figure 19. DC FM System

all regulator voltage variations must occur across Q201, R200, and R201 if the +150 to ground voltage is to be independent of voltage variation as the line voltage or load current vary. CR209 limits the maximum voltage across Q201 and R200-R201 limit the series current. Q202 is a current amplifier which causes the collector current of Q201 to increase (resistance of emitter-collector circuit drops) for a small increase in Q202 base current. The base current of Q202 increases as its base potential gets more negative since it is a PNP device. Thus, if Q204 had zero collector current, Q202 and Q201 would be saturated (i.e., large collector current, low collector-emitter voltage) and E_0 would approach E_{in}. Thus, decreasing Q204 collector current increases E_0.

Now, consider the amplifier composed of Q203 and Q204. Since CR210 represents a stable reference voltage, the collector current of Q204 must depend only on its emitter current which is inversely controlled by the emitter current of Q203, which in turn depends on the value of E_o and the setting of R207. If E_o decreases, the base current (and hence emitter current) of Q203 increases, thus decreasing the emitter current (and hence collector current) of Q204. Since we have seen before that a decreased collector current in Q204 increases E_o, regulation will occur. Since the current gain from the base of Q203 to the collector of Q201 is high, the output E_o will depend only on the setting of R207, and the drop across CR210. C204 and C210 reduce the high frequency gain of the amplifier to keep it stable.

The use of two transistors, Q203 and Q204, is to balance their base-emitter voltage change with temperature variation, thus, achieving the stability required.

A second dc voltage from the power supply is for use in the RF Unit and V400 filaments. It utilizes two silicon diodes as a full-wave rectifier with a zener diode and a transistor to maintain the proper regulated output of 7.3 volts dc. This is dropped to 6.3 volts in the RF Unit for V100 to V103 by the dc resistance in the RF filter. This function is provided by CR211 for the FM cathode follower, V400.

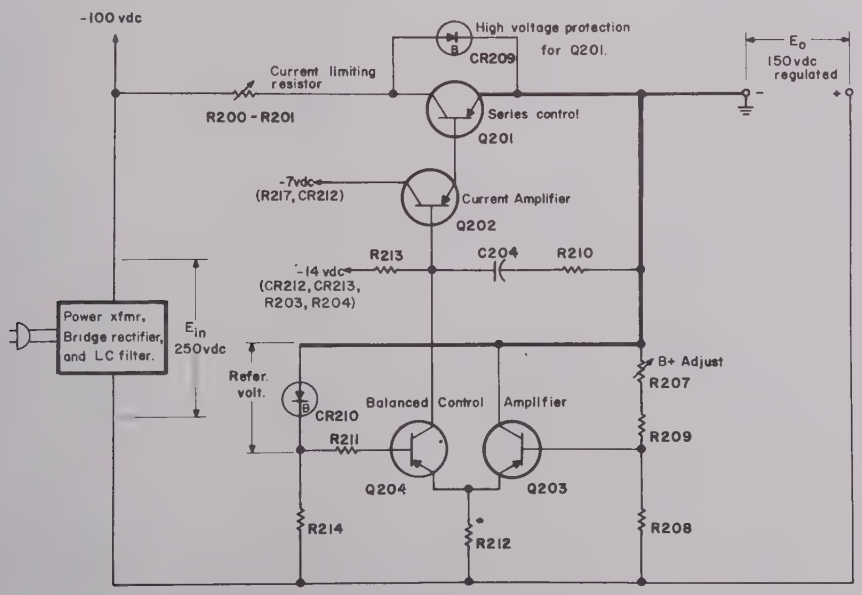


Figure 20. Power Supply B+ Regulation Circuit

SECTION V
OPERATIONAL GUIDE

INTRODUCTION

The Operational Guide is a section devoted to expanding the specifications of the 202J. This added information should assist in providing more accurate results as the capabilities and limitations of the Signal Generator are expanded upon.

PISTON ATTENUATOR

The RF Output Attenuator consists of a circular "waveguide-below-cutoff" operating in the TE_{11} Mode. This type of attenuator exhibits a theoretical 32 db attenuation for each unit of travel of the pickup probe equal to the diameter (.700 inches) of the attenuator waveguide. At levels above 50K microvolts (approximately), the attenuator pickup probe begins to emerge from the waveguide and the attenuation characteristic begins to depart from the theoretical value shown above. Thus, maximum linearity is apparent in the region below 50K microvolts and the greatest accuracy will be realized in that range. This phenomenon is reflected in the 202J specifications.

The pickup probe in the attenuator is compensated as indicated in the Theory of Operation Section. This compensation maintains a more constant output impedance resulting in a low VSWR, the maximum specified being 1.2. With a VSWR of 1.2, the associated reflected power loss would be less than 0.035 db which is considered negligible.

The dial calibration is indicative of the average RF power output. When employing a Bolometer to calibrate this generator, the carrier should be unmodulated. Amplitude modulation, with its resulting sidebands, will tend to increase the average power output, approaching a 50% increase as the carrier is modulated at 100%. Frequency modulation, however, will have no effect on the output power level, except for the effect of residual AM on FM. See FM operation.

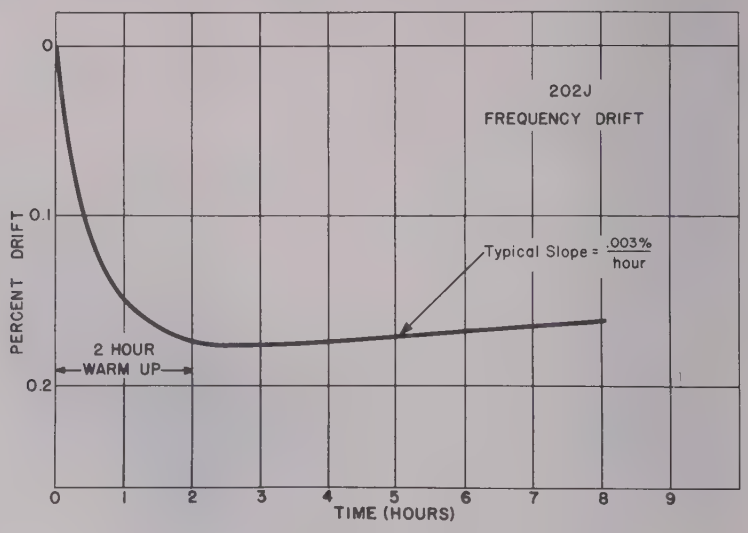


Figure 21. Long-Term Frequency Drift Characteristic Curve

FREQUENCY DRIFT DATA

The specified frequency stability of the signal generator is 0.02% or less per hour. This stability only can be maintained after an initial two-hour warmup and under stable ambient temperature conditions. After 2 hours, the typical drift is .003% per hour and after 24 hours it is .001% per hour. Typical drift data for the 202J Signal Generator over an eight hour period is shown in Fig. 21. This is typical data, however, and does not change the published specifications, since the .02% per hour figure will be approached at some frequencies by some instruments.

FM OPERATION

The 202J Modulation Meter Circuitry, in FM operation, samples the peak-to-peak amplitude of the input signal and indicates the resulting peak deviation. Peak-to-peak detection is used, as opposed to average or rms detection, so that the maximum deviation from the carrier frequency is indicated for any simple or complex waveform composed of IRIG subcarriers. Under conditions of multiple frequency modulation, with sine wave signals of random phase relationship, the resulting waveforms have equal positive and negative peak deviation over a period of time longer than the lowest input signal frequency. The time constant in the peak-to-peak detetor was chosen to give a flat response for the IRIG telemetry subcarrier frequency range of 400 cps to 70 kc.

Figure 22 shows a typical 202J FM Channel Fidelity Characteristic at 215 mc, the lowest commonly used telemetry RF carrier. The portion of the curve above 10 kc was obtained by using the "Fidelity Measurement Procedure" under Additional Information for FM Measurements, Section VI. The low frequency portion of the curve, below 10 kc, is the frequency response of the FM channel measured between the front panel terminals (EXT OSC-FM) and the FM input of the RF Unit (J102). This measurement is made with a dc coupled oscilloscope with known low frequency response. Below 10 kc, the

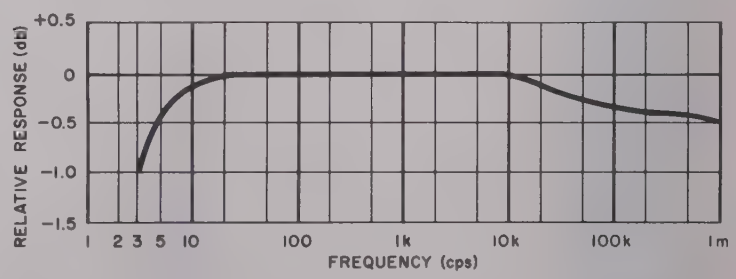


Figure 22. FM Channel Fidelity Characteristic Curve

signal response of the RF Unit filter is flat.

The FM channel fidelity varies slightly with the carrier frequency. The response for modulation frequencies above 250 kc increases with the modulation frequency as the carrier frequency is raised above 215 mc. The response for modulation frequencies above 250 kc drops as the carrier frequency is decreased from 215 mc. The fidelity limits of ±1db at a modulation frequency of 500 kc and ±3db at 1 mc are easily met.

The frequency response of the Modulation Meter increases for modulation frequencies above 500 kc to match the average frequency response of the FM channel. For the most accurate deviation setting at modulation frequencies below 100 cps and above 20 kc, some correction is needed. Figure 23 is a typical 202J FM Fidelity Correction Curve for 125 kc deviation indicated on the 150 kc scale at 215 mc carrier frequency. To get 125 kc deviation at a particular modulation frequency, adjust the modulation signal level for an indicated deviation of 125 kc plus or minus the correction obtained from the curve. For any particular instrument at various carrier frequencies a correction curve can be obtained by measuring the FM channel fidelity and Modulation Meter frequency response.

Figures 24A and 24B show typical responses of the FM channel for 100 cps and 100 kc square waves. Since the modulation meter measures the peak-to-peak amplitude of the input signal, care should be taken to minimize overshoot on the input square wave.

The modulation meter when used in the AM position actually measures "recovered AM". Thus, after adjusting the generator in the FM mode of operation, it is possible to switch only the Modulation Meter to "AM". The meter will then read incidental AM on the carrier. Typical readings are:

1. With 150 kc deviation the incidental AM will be less than 4%.
2. With 300 kc deviation the incidental AM will be less than 8%.

It is also possible to measure FM as a result of AM. To measure incidental FM, a receiver of known dynamic limiting characteristics can be used. Typical data in this regard is as follows:

1. With 50% AM at 400 cps the incidental FM will be approximately 2 kc.
2. With 50% AM at 10.5 kc the incidental FM will be approximately 5 kc.

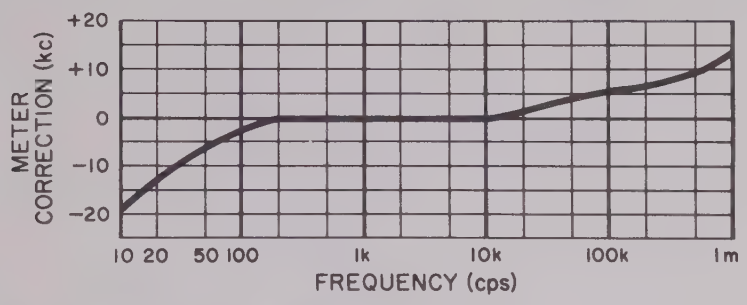
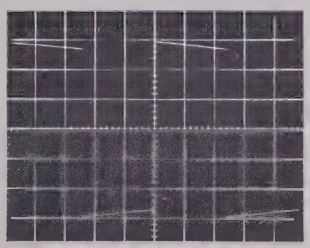
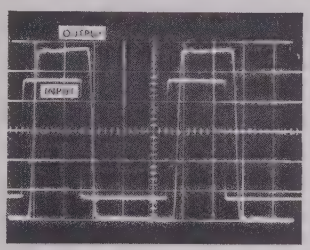


Figure 23. Typical Fidelity Correction Curve



(A) 100 cps



(B) 100 kc

Figure 24. FM Channel Square Wave Response

FM LINEARITY

In operation, the △F electrical tuning actually shifts the dc operating point of the reactance tube. This same effect occurs when an external dc control voltage is supplied to the DC FM input jack. The 202J linearity is adjusted for minimum nonlinearity with the △F control in its mid-position (knob arrow vertical) and no external dc applied. For minimum nonlinearity at deviations below 500 kc, the 202J should be operated with △F at mid-position and no external dc supplied. Fig. 25 shows the DC FM input characteristics of the 202J which is the modulator characteristic. In this figure it can be seen that the distortion increases rapidly in the negative direction above 400 kc (or —3 vdc at the DC FM input jack). For higher deviation (over 500 kc), the modulator operating point should be shifted by applying a positive dc voltage to the DC FM input. This will extend low distortion modulation capabilities to approximately 600 kc deviation.

The △F control and DC FM input circuits do not react instantaneously, thus, sufficient time should be allowed for the instrument to stabilize. The time-constant in the △F tuning control and DC FM input circuits is almost 1 second.

AMPLITUDE MODULATION

The 202J employs screen grid amplitude modulation. As indicated in section IV—Theory of Operation, the modulating signal is pre-distorted in order to minimize the distortion in the modulated carrier. At levels above 50% AM, the distortion increases appreciably as a result of nonlinearity of the screen grid modulation characteristic of the output tube (V103) and the diode circuit associated with the metering and AGC circuitry.

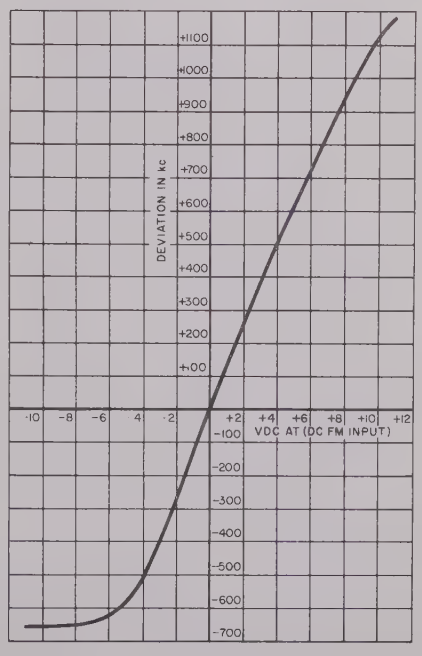


Figure 25. DC FM Input Characteristic Curve

The specification for Amplitude Modulation accuracy is ± 10% at 30% and 50% modulation. An oscilloscope display of the AM trapezoid will aid in setting modulation to desired levels if closer tolerances are required. Trapezoidal presentation of AM is discussed in the Maintenance section.

SECTION VI
MAINTENANCE

GENERAL

The 202J is a complex FM-AM Signal Generator; however, with its straight forward design, the instrument can be readily maintained and repaired in the field. With the exception of the RF Unit, all parts are accessible by removal of the top, side, and bottom covers. The RF Unit may be readily removed from the instrument for maintenance or repair. In some cases removal of the RF Unit cover will provide sufficient accessibility.

PREVENTATIVE MAINTENANCE

Ventilation

The 202J utilizes convection and conduction cooled semiconductors in the power supply, thus eliminating the need for a blower. The cabinet is adequately ventilated to disperse the heat generated within the instrument. Operating the instrument with the vents blocked will not only shorten tube and component life, but will require a much longer warmup time for frequency stabilization.

Lubrication

The 202J is adequately lubricated for the life of the instrument. The only necessity for added lubrication is for the lubricants wiped off during replacement of parts. Excessive lubrication can be damaging to contacts in electronic devices and should be avoided. To lubricate shafts, gears, bushings, etc. in the 202J, the following lubricant is recommended: Beacon No. 325 manufactured by Humble Oil & Refining Co.

Semiconductor Insulators

In some cases the semiconductors; i.e., transistors and diodes, are insulated electrically from the chassis or heat sink by material such as mica. For maximum transfer of heat to the chassis through the insulator, it is coated on both sides before assembly with silicone grease DC-4 manufactured by Dow Corning Corporation.

TROUBLE SHOOTING AND REPAIR

Tube and Transistor Replacement Guide

The Tube and Transistor Replacement Guide is primarily a checklist to show tube and transistor functions with the readjustments required after tube or transistor replacement. The "Symptoms Noted" information, like the Trouble Shooting Chart, is included as an organized starting point in the event that the instrument is not performing properly.

To gain access to the tubes and transistors, the following disassembly procedures must be used:

1. Removal of the top cover of the 202J will allow changing of tubes V300, V500, V501, V502, V600, V601, and V602.
2. Removal of the top cover and RF Unit cover will allow changing of tubes V100, V101, V102, and V103.
3. Removal of the top cover and disassembly of terminal board 307700 from mounting brackets allows changing of transistors Q202, Q203, and Q204.
4. Removal of the bottom cover of the 202J will allow changing of tube V400.
5. Removal of the top, bottom, and right side covers will allow changing of transistor Q201.
6. Removal of the top, bottom, and left side covers will allow changing of transistor Q200.

Trouble Shooting Chart

The Trouble Shooting Chart lists symptoms that could possibly develop in the instrument and details faults, probable causes of these faults, remedies, and procedures for correcting these conditions. It is suggested that this chart be used as a first step in analyzing trouble since considerable time and effort associated with unnecessary readjustment or alignment can therefore be avoided.

Voltage and Resistance Chart

The Voltage and Resistance Chart indicates normal operating conditions for the 202J with no external equipment attached. Voltages were checked with a VTVM (hp 410B). Resistance readings were made under the same conditions with power disconnected. Some resistance readings have been omitted as the readings have no significance; i.e., cases where electrolytic capacitors or semiconductor devices are connected in the circuit.

TUBE AND TRANSISTOR REPLACEMENT GUIDE

Reference Symbol	Type	Application	Readjustment Required	Symptoms Noted
V100	6688	Reactance Modulator	Bias Adj. (R107) and Frequency calibration check	No frequency modulation
V101	6AF4	RF Oscillator	Frequency calibration check	No RF
V102	6688	1st Doubler	Doubler tracking check	Weak or no RF
V103	6688	2nd Doubler	Doubler tracking check	Weak or no RF, No AM
Q200	2N1136	DC Fil Reg.	None	
Q201	2N1533	B Supply Reg.	Reg. Input Adj. (R201)	Low or no dc voltage
Q202	2N1379	Reg Driver Amp.	None	Poor regulation—low dc voltage
Q203	2N1379	Reg Amplifier	R207	Poor regulation
Q204	2N1379	Reg Amplifier	R207	Poor regulation
V300	6AW8A	AGC dc Amplifier	AGC Bias Adj. (R308)	Automatic RF level set not functioning properly
V400	6BK7B	FM Cathode Follower	R416	No frequency modulation internal or external (Modulation meter indicates).
V500	6AU6A	Audio Oscillator	Osc. Gain Adj. (R510)	No internal modulation
V501	6AQ5A	Audio Oscillator Output	Osc. Gain Adj. (R510)	No internal modulation
V502	12AU7A	AM Cathode Follower	None	No amplitude modulation
V600	6AU6A	Meter Amplifier	Mod Meter Adj. (R612)	No Modulation Meter indication
V601	6AU6A	Meter Amplifier	Mod Meter Adj. (R612)	No Modulation Meter indication
V602	6DJ8	Mod Meter Cathode Follower	None	No Modulation Meter indication

TROUBLE SHOOTING CHART

SYMPTOM	PROBABLE CAUSE	LOCALIZING AND REMEDYING FAULT
1. No RF output No RF Monitor Meter indication.	Defect in RF Unit.	Check voltages at J100 receptacle for RF Unit supply voltages. No voltage at pin #3 could indicate an open fuse in the dc filament line. Check fuse F201 on the back panel of the 202J. Next, remove RF Unit cover. (See Disassembly Procedure). Check voltages at RF filter and then proceed to the tube sockets. (See Voltage and Resistance Chart.)
2. No RF output RF Monitor Meter indicates output.	Defective Attenuator resistor.	Check dc resistance at RF output jack (J101). It should be approximately 50 ohms. A momentary connection to external equipment under test could cause the series resistor R117 in the attenuator to open. Replacement will require physical realignment of attenuator coil and recalibration of piston attenuator. (See Alignment and Adjustment Procedures.)
3. No RF output indicated on RF Monitor Meter.	Defect in meter circuitry.	Check for AM on Modulation Meter. No AM indicates defective diode (CR101), open capacitor (C121), or shorted capacitor (C149). (No output from detector circuit makes AGC system inoperative and will result in excessive RF output.) Also check for dc potential at Monitor Meter.
4. Weak RF as indicated by RF Monitor Meter.	Low B + supply.	Check power supply output voltage. Referring to Fig. 26 check B+ to chassis to B— voltage relationship. It can be seen from the basic circuitry that filament to cathode shorts in tubes such as V300 and V600 can change the B+ to ground circuit balance. It is important that the described relationship be maintained. Note: It is suggested that when a high resistance short exists in the 202J, the power plug P100 from the RF Unit be removed to help isolate the defect.
5. No FM deviation		
A. No FM deviation internal or external as indicated in output of 202J.	Defective Reactance Modulator (V100).	Check for proper operating voltages on tube. See Voltage and Resistance Chart.
B. No FM deviation from internal oscillator. Meter indicates deviation.	Defective FM Cathode Follower (V400B).	Check for proper operating voltages on tube. See Voltage and Resistance Chart.
C. No FM deviation from external modulating source. Meter indicates deviation.	Defective FM Cathode Follower (V400A).	Check for proper operating voltages on tube. See Voltage and Resistance Chart.
6. No AM, internal or external as indicated on Modulation Meter.	Defective AM Cathode Follower (V502).	Externally, the output of the AM Cathode Follower can be checked at J500 Ext Pulse Jack by using a phone plug on an oscilloscope lead and inserting lightly into jack to make connection, without opening jack contacts. (There is approximately 45 vdc at this point, so necessary precautions must be observed.)
	Defective J500 Ext Pulse Jack.	Check for dc potential on pin #4 of J100. Poor contacts on J500 opens screen grid circuit of V103. This situation is also indicated by weak RF.
	Defect in Modulation Meter circuitry.	See Symptom #2. It should be noted that the RF Monitor Meter does not indicate in either AM or FM when this problem exists.
7. No Internal modulation, AM or FM.	Defective audio oscillator.	Check plate (pin #5) of V501 with scope for audio oscillator output. If no output, check resistance lamp RT500 in cathode of V500. Check operating voltages on V500 and V501. See Voltage and Resistance Chart. Note: If RT500 is changed the Osc Gain Adj (R510) will require checking. (See Adjustment and Calibration.) Externally the audio oscillator output can be checked on the FM Ext Osc posts with the INT MOD switch in the FM position.
8. Insufficient AM	Weak output from internal audio oscillator.	Check Osc Gain Adj (R510). Change resistance lamp RT500 in cathode of V500 and recheck output. (See note above.)
9. Intermittent RF	Internal plugs loose in sockets.	Check P100 and P102 for proper seating in receptacles J100 and J102.
10. Microphonism	RF Unit not floating free.	Check to assure shipping devices for securing RF Unit have been loosened or removed. (See Installation.)
11. Automatic level set does not hold meter red line for the range of the instrument.	Defective AGC Amplifier circuitry.	Check for proper operating voltages on V300. It should be noted that the RF Unit is operating as RF Monitor Meter indicates; however, the circuitry in the RF Unit which is associated with the AGC amplifier can also be at fault. (See Sympton 3.)

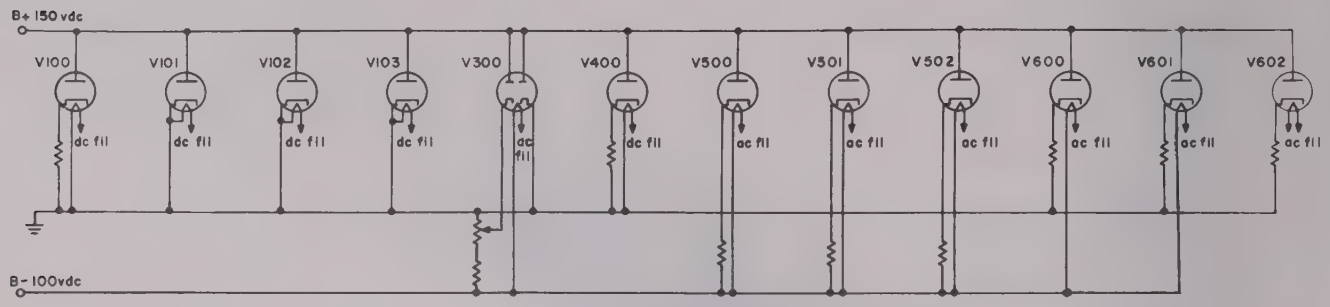
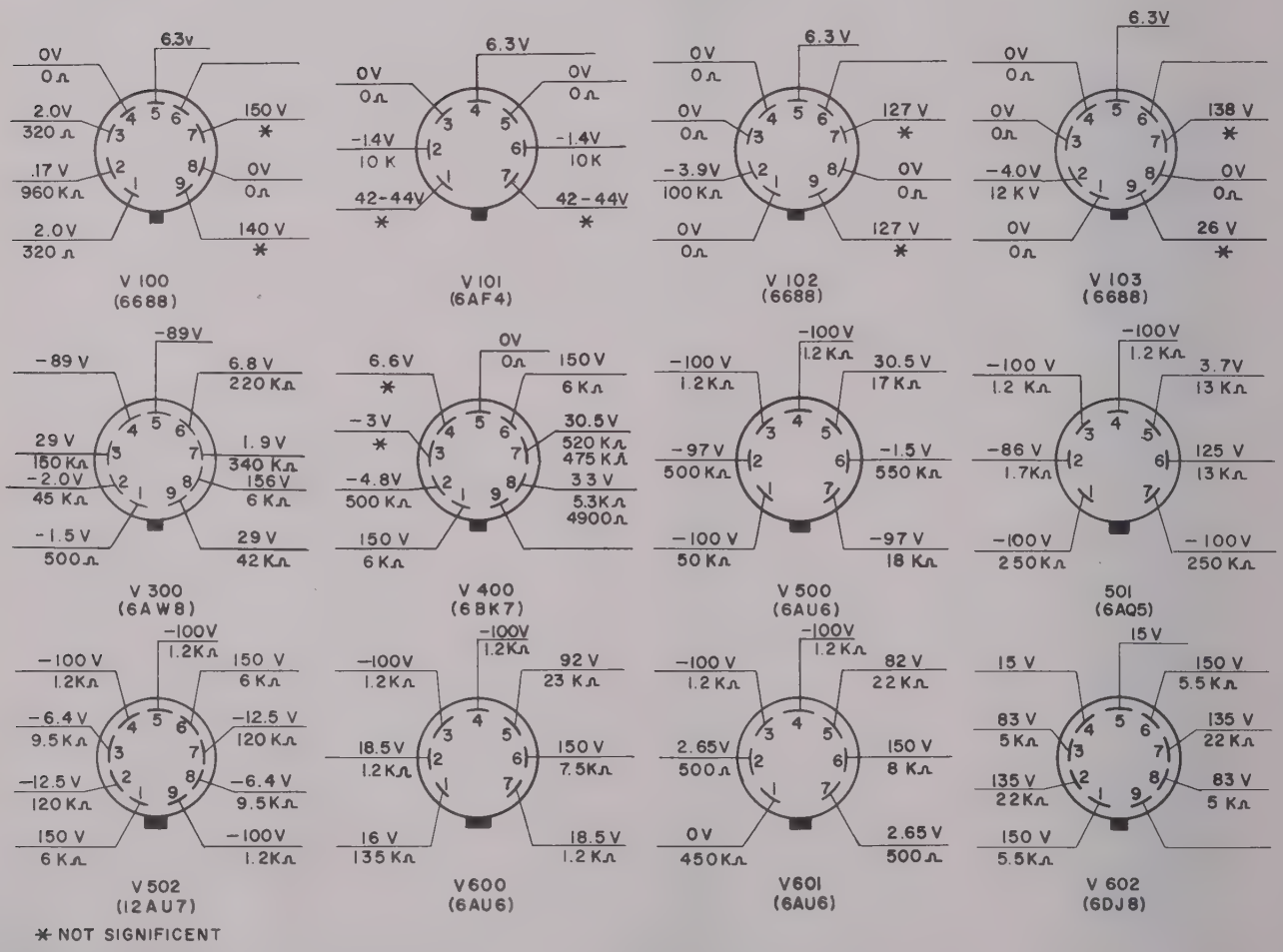
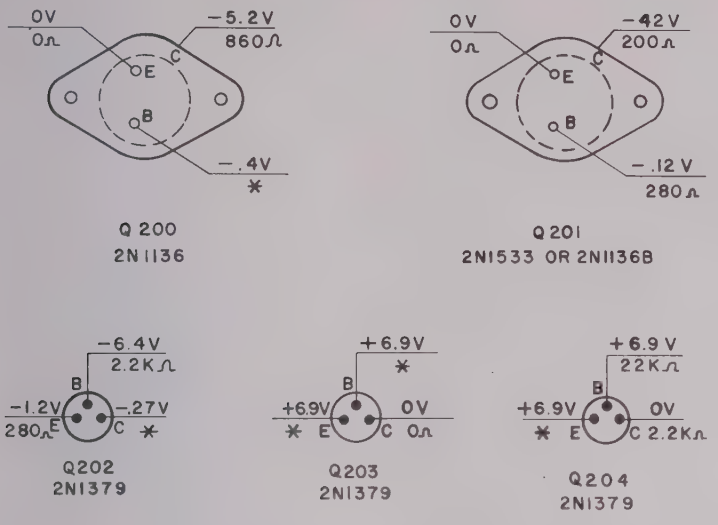


Figure 26. Basic Circuit 202J Power Distribution System



VOLTAGE AND RESISTANCE CHART — TUBES



VOLTAGE AND RESISTANCE CHART — TRANSISTORS

MECHANICAL DISASSEMBLY PROCEDURES

Top and Bottom Covers

1. Remove four screws.
2. Slide cover toward rear of instrument to disengage rear foldover of cover.

Right and Left Side Covers

1. Remove top and bottom covers (See above).
2. Remove four machine screws and nuts securing side covers to instrument.

RF Unit Cover

1. Remove three tierod nuts and washers.
2. Loosen screws securing the RF Unit end plate.
3. Slide end plate toward rear of instrument to disengage screws from slots.
4. Grasp cover and slide it toward rear of instrument with as little tilting motion as possible. It is imperative that the cover retain its original shape so as to fit securely back in place on the RF Unit housing. A bent or damaged edge on the cover will allow a small amount of RF leakage beyond the very low original limit.

RF Filter

1. *Carefully* remove RF Unit cover (See above).
2. Disconnect plugs P100 and P102 from main chassis.
3. Remove cable clamp on RF Unit housing.
4. Unsolder leads connected to filter.
5. Loosen large nut securing the RF Filter.
6. Slide RF Filter out of RF Unit housing.

At this point the RF Filter is available for maintenance and repair. For replacement of the complete assembly, the plugs (P100 and P102) must be removed from the cables.

RF Unit

1. Disconnect P100 and P102 plugs from main chassis.
2. Rotate frequency control shaft until set screws in coupling are accessible and remove two set screws from coupling on end toward front of instrument. The coupling can remain attached to the RF Unit.

NOTE: The frequency dial setting should be noted at this point to aid in the reassembly of the RF Unit.

CAUTION: There is no stop on the RF Unit frequency control shaft. Rotating the frequency control shaft with the RF Unit out of the instrument, will cause the gear on the frequency control shaft to disengage from the split gear on the rotor shaft. See Mechanical Disassembly Procedure—RF Unit Frequency Control Shaft for engagement procedure.

3. Rotate attenuator control to stop with attenuator piston completely into the tube. Note dial setting (dial setting vs attenuator stop) to aid in the reassembly of the RF Unit. Back off attenuator control to make set screws accessible. Remove two set screws from coupling at end toward rear of instrument. The coupling will remain attached to the front panel shaft.
4. Remove RF Output jack from front panel of 202J.
5. Disconnect ground strap from base of shock mount.
6. Remove four screws securing RF Unit brackets to shock mounts.
7. Lift out RF Unit complete with brackets and cables.

Before re-installing the RF Unit in the 202J, the following checks should be made to insure against excessive RF leakage:

1. The RF filter should be secured with the grounding washer in place. The large hex nut should be tight.
2. The attenuator should be fastened securely by the four mounting screws.
3. The RF Unit cover should be of proper rim size to fit tightly into the RF Unit casting. At the factory, the cover is placed on a sizing jig (Fig. 27) before assembly to the RF Unit to insure proper size and roundness of the rim.

After the RF Unit is replaced, the 202J will require a frequency calibration and attenuator calibration check.

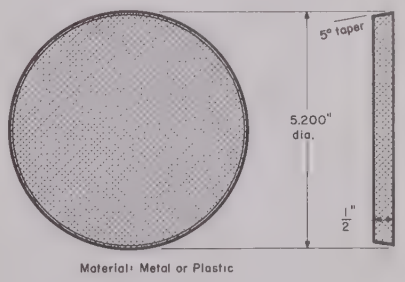


Figure 27. RF Unit Cover Sizing Jig

Piston Attenuator

The Piston Attenuator assembly may be removed completely from the RF Unit, but this procedure is not recommended. For repairs such as resistor replacement, if disassembly is required, the piston only should be removed from the tube. The piston is removed as follows:

1. Referring to Fig. 64, the collars, gears, and stop plate on shaft (307935) are loosened to allow removal of the shaft. Make note of order of parts on shaft for reasembly purposes.

2. Remove three screws from piston bushing.

3. Slide piston out of attenuator.

During reassembly, the tension on the spring loaded gears will have to be adjusted. This is accomplished, after shaft parts are secured, as follows:

1. Attach a front panel knob directly to the attenuator shaft (for check purposes only).

2. Collar (307995) is loosened and rotated until springs are tight but not under tension. Secure collar.

3. Oscillate knob. Check for looseness in gears as detected by feel during knob rotation.

4. Loosen and rotate collar (307995) to increase tension on spring. Secure collar and recheck for looseness.

5. Repeat step 4 until looseness just disappears. Too much tension will show up as drag or stiffness of attenuator control. This in turn will make small incremental setting of the control difficult.

Terminal Board (BRC Part No. 307700)

This terminal board mounts three transistors and must be disassembled from its brackets to gain access to the transistors for replacement.

1. Remove four machine screws with lockwashers from corners of the terminal board.

2. If necessary, the terminal board assembly can be completely removed from the 202J by unsoldering five leads.

RF Monitor Meter

1. Remove two nuts securing lugs to meter connections.

2. Slide lugs and capacitor (C300) assembly off of meter connections.

3. Remove four nuts securing meter corners. Access holes are provided in the instrument framework.

4. Slide meter out of front panel.

Modulation Meter

1. Remove two nuts securing lugs to meter connections.

2. Slide lugs and diode (CR600-CR603) assembly off of meter connections.

3. Remove four nuts securing meter corners. Access holes are provided in the instrument framework.

4. Slide meter movement out of front panel.

Front Panel Assembly

Several components can be replaced only after moving the front panel. This procedure gives the method required to gain access to these parts.

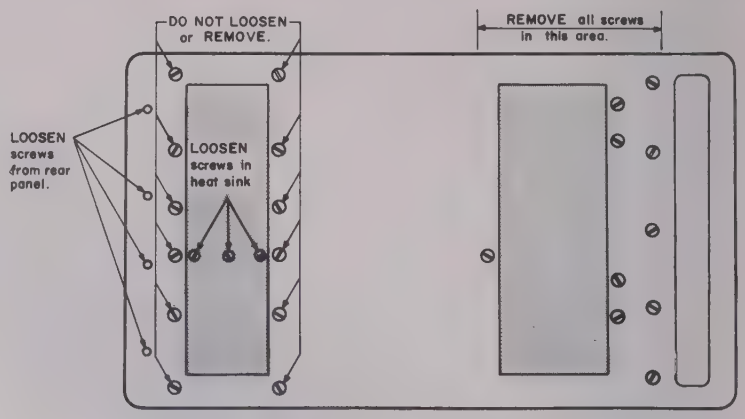


Figure 28. 202J Side View - Front Panel Removal

1. Remove the following control knobs:
   a. VERNIER (5A)
   b. FREQUENCY MEGACYCLES (4A)
   c. △F KC (19A)
   d. △F KC LOCK (19B)
   e. MICROVOLTS DBM (8A)
2. Remove the top and bottom covers.
3. Remove adhesive backed trim strips (308137-51) on either side of the 202J.
4. Remove or loosen screws as indicated in Fig. 28. This should be done on both sides of the instrument.
5. Spring side castings away from front panel to disengage front panel from tabs at top and bottom of side castings. Spring one side at a time, moving front panel about an inch forward.
6. Tilt front panel forward with care to avoid damage to components, wires and cables. In this position all repairs can be done.

Gear Assembly

It is not recommended that the gear assembly be repaired in the field. Referring to Fig. 65, the gear assembly (307793) is replaced as a unit. To remove this assembly use the following procedure.

1. Remove the following control knobs:
   a. VERNIER (5A)
   b. FREQUENCY MEGACYCLES (4A)
   c. △F KC (19A)
   d. △F KC LOCK (19B)
2. Remove top and bottom covers.
3. Remove RF Unit, but do not remove RF Unit cover. (See RF Unit disassembly.)
4. Remove nut and machine screw at bottom edge of gear assembly.
5. Remove screw and lock washer from either end of gear assembly angle bracket (along front top edge of 202J).
6. Remove gear assembly angle bracket. Fiducials and scale masks remain attached to this bracket.
7. Remove △F KC control (R410) by disassembling the dial scale and lock assembly. Use open-end wrench to remove nut securing R410 to gear assembly rear plate.
8. Remove gear assembly and dial scales from 202J.
9. Dial scales may be removed for replacement of gear assembly.

NOTE: Do not disassemble gear mechanism.

RF Unit Rotor Assembly

1. Remove RF Unit from 202J.
2. Remove attenuator assembly.
3. Remove RF Unit housing.
4. Remove rotor shaft wiper from top of shaft in 2nd Doubler compartment.
5. Loosen rotor shaft wipers in 1st Doubler and Oscillator compartments.
6. Loosen nut securing end bearing at rear of RF Unit.
7. Loosen end bearing while holding rotor shaft.
8. Lift out rotor assembly.

NOTE: The ends of the rotor assembly shaft rest against pyrex ball bearings which will drop out during disassembly.

When reassembling the rotor shaft, the adjustment on the end bearing should be done with extreme care. The end bearing adjustment should just elim-

inate any end play. It should allow free rotation of the rotor such that the starting torque required to rotate the frequency shaft at the front of the RF Unit should not exceed 6 inch ounces.

RF Unit Stator Assembly

1. Remove RF Unit from 202J.
2. Remove RF Unit Rotor Assembly from RF Unit.
3. Remove two machine screws securing the stator base.
4. Lift out stator assembly.

NOTE: When replacing the stator assembly it should be noted that, in full mesh condition, the stator and rotor plates edges should be in mechanical alignment. Shims are used between stator plate assembly and insulator base to insure mechanical lineup.

RF Unit Frequency Control Shaft

(Fig. 29)

1. Remove RF Unit from 202J.
2. Loosen setscrews in gear and in collar.
3. Remove "C" washer from shaft at front of RF Unit.
4. To remove shaft, slide shaft toward rear of RF Unit.

When reassembling frequency control shaft, the split gears will have to be spring loaded properly as follows:

1. With split gear assembly disengaged from the gear on the frequency control shaft, rotate one gear with respect to the other to take up slack in spring.
2. After spring is tight, but not under tension, rotate one gear approximately 2½ to 3 teeth with respect to the other.
3. Holding tension on split gears, rotate the split gear assembly until it engages in the gear on the frequency control shaft. In this condition, the loading on the springs should be correct as to meet the requirement for torque on frequency control shaft described under Mechanical Disassembly Procedure—RF Unit Rotor Assembly.

SPECIAL INSTRUCTIONS FOR TRANSISTORS AND DIODES

Semiconductors can be damaged by excess heat such as might be imposed by a soldering iron. When replacing transistors and diodes, always hold wire between semiconductor and terminal with a pair of long-nose pliers while soldering to help to dissipate some of the heat. When this practice cannot be followed, avoid long exposure to heat from the soldering iron. Use a low wattage iron.

Q200

This transistor is mounted with the collector insulated from chassis ground by means of a mica insulator and transistor socket or shoulder washers on screws. See special instructions under Preventative Maintenance - Semiconductor Insulators.

Q201

This transistor is mounted with the collector insulated from chassis ground by means of a mica insulator and transistor socket or shoulder washers on screws. One mounting screw on this transistor is isolated from the transistor where the transistor socket is not used. Check before disassembly to avoid incorrect replacement procedure. See special instructions under Preventative Maintenance-Semiconductor Insulators.

Q202, Q203, and Q204

These transistors are soldered in. Remove terminal board (307700) when replacing transistor.

CR100, CR200, CR201, CR202, CR203, CR206, CR207, CR210, CR211, CR212, CR213, CR300, CR301, CR302, CR303, CR500.

These diodes are soldered in. Observe polarity before replacement.

CR101

This diode fits into a clip. Observe polarity before replacement.

CR204, CR205, CR208, CR209, CR400

These diodes are mounted to a heat sink. In some cases mica insulators are used to electrically isolate the diode from chassis ground. See special instructions under Preventative Maintenance-Semiconductor Insulators.

CR600, CR603

These diodes are soldered together and connected across the Modulation Meter. Observe polarity before replacement.

CR601, CR602

These diodes are soldered to terminals on a terminal strip. Observe polarity before replacement.

ADJUSTMENT AND CALIBRATION

Any tolerances listed in this section are the limits indicated by the Specifications in Section II. Factory adjustments are made to considerably closer tolerances corresponding to standard practice in the industry. Field adjustments to closer than specified tolerances are possible if time and patience are used.

Recommended Equipment List

The following instruments are recommended for use in the adjustment and calibration of the 202J. Pertinent information is given for substitution purposes.

1. hp 412A dc VTVM

Range: 1 mv to 1000 v (full range not required).
Accuracy: ±1% full scale.

2. hp 400H ac VTVM

Range: 1.0 mv to 300 v.
Frequency Range: 10 cps to 4 mc.
Accuracy: ±1% 50 cps to 500 kc.
±5% 10 cps to 4 mc.

3. hp 330B Distortion Analyzer

Frequency Distortion Range: 20 cps to 20 kc.
Accuracy: ±3%.
Input Level: At least 1 v rms

4. hp 5243L Electronic Counter

Frequency Range: 0 cps to 20 mc.

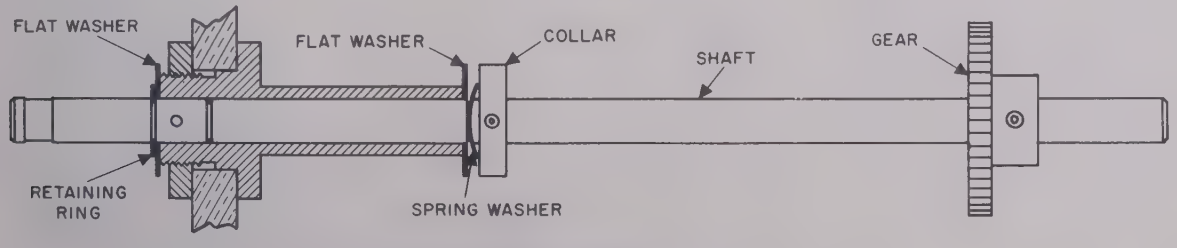


Figure 29. RF Unit Frequency Control Shaft

5. hp 5253A Frequency Converter
Use with hp 5243L Electronic Counter for frequency range of 100 mc to 512 mc.

6. High Output Audio Oscillator
Capable of 50 v (into 6000 ohms) output over audio range.
Frequency Range: 20 cps to 20 kc.
Accuracy: ±1%.

7. hp 540B Transfer Oscillator
Frequency Range: 10 mc to 12.4 K mc.
Type of Input Signal: CW, AM, FM, or Pulse.

8. hp 130C Oscilloscope
Sensitivity: 0.2 mv/cm.
Frequency Range: 0 to 500 kc.

9. Signal Generator with same RF frequency range as 202J

10. hp 431A Power Meter
Power Range: 10 μw to 10 mw.
Accuracy: ±3% of full scale.

11. hp 478 Thermistor Mount for use with hp 431A Power Meter

12. hp 400D VTVM
Used in the linearity measurement set-up. For this application a slight modification is made during use (See Fig. 38).

13. hp 650A Test Oscillator
Frequency Range: 10 cps to 10 mc.
Accuracy: ±2% to 100 kc, ±3% 100 kc to 10 mc.
Output: .015 watts into 600Ω (Approximately 3v).

14 hp 466A ac Amplifier
Frequency Response: ±.5 db 10 cps to 1 mc.
Gain: 20 db or 40 db at 1 kc.
Distortion: <1% 10 cps to 100 kc.
Output: 50Ω in series with 100 μf.

15. Voltage Calibrator
Range: 0-10 v rms.
Frequency: 1000 cps.
Accuracy: ±0.5%.

POWER SUPPLY

EQUIPMENT REQUIRED

1. hp 412A dc VTVM or equivalent.*
2. hp 400H ac VTVM or equivalent.*
3. Variable 60-cycle power source with meter.

B+ SUPPLY

Preliminary Setup

1. INT MOD switch in "OFF" position.
2. RF METER ADJ (R300) and MOD METER ADJ (R612) to full counter-clockwise position.
3. AC VTVM and dc VTVM connected across output filter capacitor (C202).

Adjustment

1. With 115 vac input to 202J, adjust R207 for 150 vdc ±0.5 v as read on dc VTVM. Vary input voltage to 202J from 105 to 125 vac. DC output should not vary more than ±0.5 vdc.
2. With 104 vac input to 202J, adjust Ref Input Adj (R201) for maximum resistance without introducing ripple on B+. Use ac VTVM or oscilloscope to observe ripple.
3. Check ripple over 105 to 125 vac input range. Voltmeter reading of ripple must not exceed .0015 vac. (When checked with oscilloscope, ripple must not exceed .005 peak-to-peak.)

DC FILAMENT SUPPLY CHECK

1. With 115 vac input to 202J, the dc filament voltage at pin 3 of J100 should be 7.3 ± 0.5 vac.
2. When varying input voltage from 105 to 125 vac, the dc filament voltage should not vary more than 0.15 v.
3. Using an oscilloscope ,check ripple over 105 to 125 vac input range. The ripple must not exceed 0.2 v peak-to-peak.

MODULATION OSCILLATOR

EQUIPMENT REQUIRED

1. hp 400H ac VTVM or equivalent.*
2. hp 330B Distortion Analyzer or equivalent.*
3. hp 5243L Electronic Counter or equivalent.*

GAIN ADJUSTMENT

Preliminary Setup

1. INT MOD Switch—AM
2. FREQ CPS—400
3. AM Control—fully clockwise.
4. ac VTVM connected across AM EXT OSC terminals.

Adjustment

1. Adjust R510 (OSC GAIN ADJUST) for 30.0 v rms at AM terminals.
2. Voltages at all positions of FREQ CPS switch should be 30.0 v ± 3 v rms.

NOTE: The voltage in the 70 kc and 100 kc positions will be effected by the frequency adjustment. See oscillator frequency check.

DISTORTION CHECK

Preliminary Setup

1. INT MOD switch—FM
2. FREQ CPS switch—400.
3. Connect 2.7 K ohms resistor across FM EXT OSC terminals. Attach distortion analyzer to FM EXT OSC terminals.

Measurement

Distortion should be less than 0.50%.

NOTE: If distortion is too high, change audio oscillator output tube V501 or oscillator cathode bias lamp (RT 500). If tube or lamp is changed, repeat gain adjustment of Modulation Oscillator.

OSCILLATOR FREQUENCY CHECK

Preliminary Setup

1. INT MOD switch—FM.
2. FREQ CPS switch—all frequencies.
3. Attach Electronic Counter to FM terminals.

Measurement

Check each frequency of the internal modulation oscillator. Frequencies should be within ±5%. The 70 kc and 100 kc positions can be adjusted by trimmer capacitors; C504 for 70 kc adjustment and C509 for 100 kc adjustment.

Modulation Meter Circuitry

EQUIPMENT REQUIRED

1. hp 412A dc VTVM or equivalent.*
2. hp 400H ac VTVM or equivalent.*
3. hp 650A Test Oscillator or equivalent.*
4. hp 130C Oscilloscope or equivalent.*
5. High Output Audio Oscillator.*
6. BRC 202J or equivalent.*
7. GR874VR HF Diode Mixer.
8. Voltage Calibrator.*

MODULATION METER ADJUSTMENT

Preliminary Check

With MOD METER switch on FM, DEV KC switch on 15, and INT MOD switch in the OFF or AM position. the meter will bounce when FM control is turned. The following adjustment will reduce the bounce due to rotation of FM control.

Adjustment

Attach dc VTVM from Pin No. 3 of V400 (6BK7) to chassis ground. Adjust for 0 volts or as close as possible with R416. This adjustment reduces transients which occur when the FM control is rotated rapidly.

*See Recommended Equipment List under Adjustment and Calibration.

MODULATION METER CHECK — FM

Preliminary Setup

1. INT MOD switch—OFF.
2. MOD METER switch—FM.
3. DEV KC—15.
4. FM control — Maximum counterclockwise.

Check

Check MODULATION meter for electrical zero.

RANGE RATIOS

Preliminary Setup

1. MOD METER switch—FM.
2. DEV KC—150.
3. INT MOD switch—OFF.
4. Attach Voltage Calibrator to FM EXT OSC terminals.
5. Set Voltage Calibrator for 1000 cycles with an output of 1.0 v rms.

Calibration and Check

1. Adjust FM control to 150 kc full scale.
2. Change DEV KC switch to 300 kc. Change Voltage Calibrator output to read full scale on Modulation Meter. The Voltage Calibrator reading should be nominally 2.0 v rms.
3. Change DEV KC switch to 30 kc. Change Voltage Calibrator output to read full scale on Modulation Meter. The Voltage Calibrator reading should be nominally .2 v rms.
4. Change DEV KC switch to 15 kc. Change Voltage Calibrator output to read full scale on Modulation Meter. The Voltage Calibrator reading should be nominally .1 v rms.

MODULATION METER LINEARITY CHECK

Preliminary Setup

1. MOD METER switch—FM.
2. INT MOD switch—OFF.
3. DEV KC switch—15.
4. Attach Voltage Calibrator to FM EXT OSC terminals.
5. Set Voltage Calibrator output to 0.1 v rms at 1000 cps.
6. Adjust FM control for full scale reading on MODULATION meter.

Linearity Check

1. Using the controls on the Voltage Calibrator, reduce the output until the MODULATION meter reads, "10 kc". The Voltage Calibrator reading should be .0667 v rms.
2. Reduce the Voltage Calibrator output until the MODULATION meter reads "5 kc". The Voltage Calibrator reading should be .0333 v rms.
3. Change the DEV KC switch to 300. Set the output of the Voltage Calibrator to 2.0 v rms (1000 cps). Adjust the FM control for full scale reading on the MODULATION meter. Using the controls on the Voltage Calibrator, reduce the output to read, "200 kc" on the MODULATION meter. The Voltage Calibrator reading should be 1.332 v rms.
4. Reduce the voltage calibrator output until the MODULATION meter reads "100 kc". The VTVM reading should be .667 v rms.

MODULATION METER FREQUENCY RESPONSE

Preliminary Setup

1. INT MOD switch—OFF.
2. MOD METER switch—FM.
3. DEV KC switch—15.
4. Attach test oscillator and ac VTVM to FM EXT OSC terminals.
5. Set test oscillator output to 0.2 v rms at 400 cps.
6. Adjust FM control for full scale reading on MODULATION meter.

Frequency Response Check

1. Change frequency of test oscillator from 400 cps to 30 cps. Readjust control on test oscillator for full scale reading on the MODULATION meter. The VTVM reading should be nominally .20 v rms.
2. Change frequency of test oscillator from 30 cps to 1 mc. Readjust control on test oscillator for full scale reading on MODULATION meter. The VTVM reading should be nominally .20 v rms.
3. Change DEV KC switch to 300. Set test oscillator to 2.0 v rms at 400 cps. Adjust FM control for full scale reading on MODULATION meter.
4. Change frequency of test oscillator from 400 cps to 30 cps. Readjust control on test oscillator for full scale reading on MODULATION meter. The VTVM reading should be nominally 2.0 v rms.
5. Change frequency of test oscillator from 30 cps to 1 mc. Readjust control on test oscillator for full scale reading on MODULATION meter. The VTVM reading should be nominally 2.0 v rms.

MODULATION METER CHECK — AM

NOTE: The following procedure can only be performed after the FM Modulation Meter Adjustment, as described under Deviation Measurement.

Preliminary Setup

1. INT MOD Switch — OFF.
2. MOD METER Switch — AM.
3. FREQUENCY MEGACYCLES — 232 mc.
4. Connect high output audio oscillator (400 cycles) to AM EXT OSC terminals and horizontal input terminals on oscilloscope (Fig. 30). Connect output of diode mixer to vertical input of scope. Adjust generator to same frequency (232 mc) and observe beat note on oscilloscope. Tune the frequency of the second signal generator away from zero beat until a clean rectangle is observed. Adjust audio oscillator and vertical gain of scope to obtain a trapezoidal pattern (Fig. 31) with a ratio of 3.3 to 10, or 3.3 scope divisions on one side and 10 scope divisions on the other.

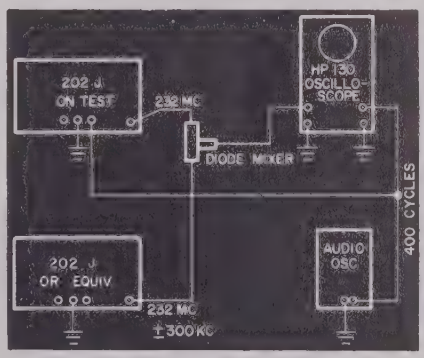


Figure 30. Setup for Modulation Meter Check — AM

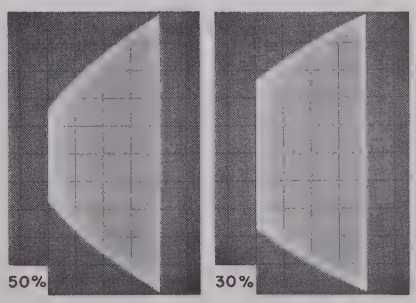


Figure 31. Trapezoidal Scope Presentations — AM

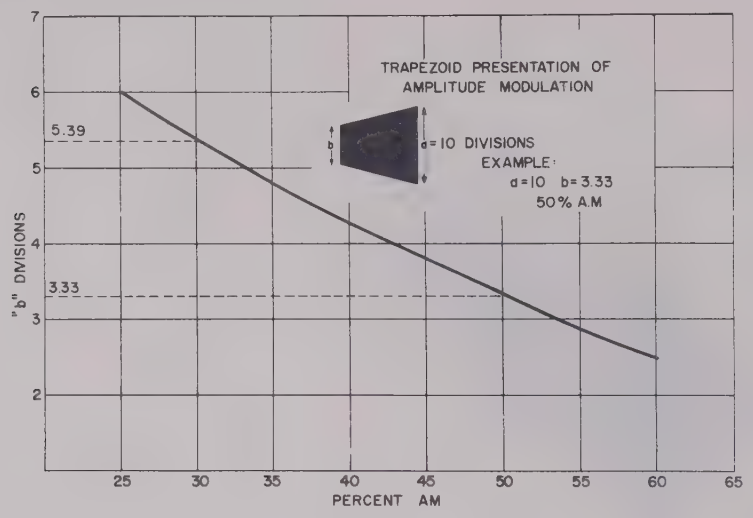


Figure 32. Percent Modulation Chart — AM

Calibration and Check

1. The amplitude modulation is now at 50%. Adjust Gain Adj (R721) for a reading of 50% on Modulation Meter.

2. Adjust audio oscillator level for Modulation Meter reading of 30% AM. (Refer to Fig. 32 for intermediate values of % modulation). Change vertical gain on scope to 5.39 scope divisions on low side of trapezoid. The ratio should be 5.39 to 10. The oscilloscope reading is 30% ±10% (Fig. 31).

3. Disconnect horizontal input to oscilloscope and temporarily remove audio oscillator. Adjust vertical gain of scope to obtain a vertical straight line of 4 divisions.

4. Reconnect audio oscillator and increase output until meter reads 100%. Scope readings should be 8 divisions ± 20%.

5. Adjust AM to 30% reading on meter. Retune RF Signal Generators to 195 mc. Observe trapezoid to determine actual % AM.

6. Increase AM input to 50% on meter. Observe trapezoid to determine actual % AM.

7. Repeat 30% and 50% checks at 270 mc.

Modulating Circuits

AM DISTORTION

NOTE: The following procedure can only be performed after the FM Modulation Meter Adjustment, as described under Deviation Measurement.

Equipment Required

1. Use the same set-up as shown in Fig. 30 for Modulation Meter Check-AM and add:

2. hp 330B Distortion Analyzer or equivalent.*

3. Shielded probe for above with 10K resistor in series.

Preliminary Setup

1. Add distortion analyzer to set-up in Fig. 30. The distortion analyzer is connected to the 202J as shown in Fig. 33.

2. INT MOD Switch — OFF.

3. Audio oscillator input to read 50% modulation (as shown in trapezoidal presentation on oscilloscope).

Measurement

1. Repeat distortion measurement at 232 mc. Distortion should be less than 8%.

2. Repeat distortion measurement at 270 mc. Distortion should be less than 8%. Increase AM input for 100% AM on meter.

3. Repeat distortion measurement at 195 mc. Distortion should be less than 20%.

4. Repeat distortion measurement at 232 mc. Distortion should be less than 20%.

5. Repeat distortion measurement at 270 mc. Distortion should be less than 20%.

The diode detector in the RF Unit will cause distortion at high modulation levels. If distortion is exceptionally high, reduce the % modulation to less than 100%, but no less than 80% (80% on meter is 245 on 0-300 scale).

RF Alignment

The following information is for the complete factory alignment of a new instrument. During maintenance or repair of an instrument, a certain amount of realignment might be required. It is important that only areas affected by repair should be aligned. Thus, only the part of the procedure pertinent to the instrument being serviced should be used.

Tube replacement will necessitate dial slipping and/or trimmer adjustment **ONLY.**

EQUIPMENT REQUIRED

1. hp 5243L Electronic Counter and 5253A converter or equivalent.*

2. hp 130C Oscilloscope or equivalent.*

3. Oscilloscope Probe with 150 K ohm resistor in series.

4. hp 431A Power Meter.

5. Extension Cable for J100 to P100 (approximately 2 feet long).

6. Extension Cable for J102 to P102 (approximately 2 feet long).

7. Tuning Dial (BRC No. 306099).

The first part of the alignment procedure is performed with the RF Unit out of the 202J cabinet. This portion of the alignment will only be required if major repairs are performed on the RF Unit. Touch-up and final alignment are done with the RF Unit in place.

*See Recommended Equipment List under Adjustment and Calibration.

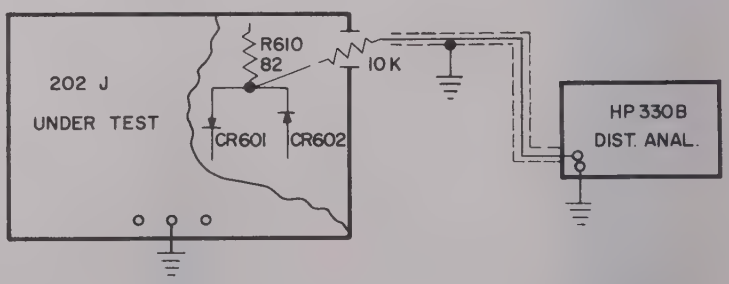


Figure 33. Setup for AM Distortion Check

OSCILLATOR ALIGNMENT

Preliminary Setup

With the RF Unit removed from the 202J and the cover off, reconnect P100 and P102 plugs to the main chassis. Additional extension cables may be used for convenience. Turn the 202J power on. Attach tuning dial (BRC No. 306099) to shaft. Attach indicator to RF Unit housing. Align dial so "O" coincides with full mesh of oscillator rotor plates. Set ΔF KC control to zero (arrow on knob pointing up). Trimmer capacitors C108, C116, and C122 should be set to mid-capacitance. Attach frequency counter to RF output jack. Turn attenuator to maximum output.

Alignment

1. Set dial to 195 mc. Adjust coil T100 until counter reads 195 mc ±0.5% **

NOTE: If oscillator frequency is low, decrease inductance by spreading windings on coil. If frequency is high, increase inductance by moving windings closer together.

2. Set dial to 270 mc. Adjust trimmer C108 until counter reads 270 mc ± 0.5%.

3. Recheck frequency calibration at 195 mc. Adjust coil T100 if necessary.**

4. Reset dial to 270 mc and check calibration. Adjust trimmer C108 if necessary.

5. Change dial to 260 mc.**

It will be noted that the end plates of the rotor section of the ganged variable capacitor are segmented. These small sections are used for tracking across the band at 10 mc increments. The rotor plate just going into mesh is adjusted to give a reading of 260 mc ±0.5% on the counter. To lower frequency, decrease plate spacing. To raise frequency, increase plate spacing.

NOTE: Adjustments to be made to segmented plate just going into mesh *only*.

6. Repeating tracking of rotor plate at 250 mc.**

7. Repeat tracking of rotor plate at 240 mc.**

8. Repeat tracking of rotor plate at 230 mc.**

9. Repeat tracking of rotor plate at 220 mc.**

10. Repeat tracking of rotor plate at 210 mc.**

11. Repeat tracking of rotor plate at 200 mc.**

12. Return dial to 270 mc. Recheck full range of 202J in 5 mc increments touching up when necessary. Upon completion of this step all dial calibration points should fall within ±0.5%.

13. At this point the linearity measurement (See Linearity Measurement) should be made and the reactance tube (V100) Bias Adj (R107) should be set for minimum nonlinearity. The control should be locked. Recheck step 12 above after adjusting R107.

14. Coil T100 should now be coated with "Q Max" to hold wires in place to avoid changing of frequency. This preparation should be allowed to dry for 24 hours after which Step No. 12 should be repeated.**

1ST DOUBLER ALIGNMENT

Alignment of the first doubler is done by a visual method utilizing an oscilloscope.

Preliminary Setup

Using 150 kc deviation set on modulation meter, and 50 cps modulating frequency, the horizontal input of the oscilloscope is connected to the EXT OSC FM posts of the 202J. The vertical input is connected via the 150 k ohm scope probe to the grid of the second doubler (V103) Pin 2.

Alignment

1. With frequency dial on 270 mc, the 1st doubler trimmer is used to center the resonant frequency on 270 mc dial indication (135 mc). Fig. 34 shows proper alignment.

2. Set frequency dial on 260 mc.**By bending 1st Doubler capacitor rotor plates, in the same manner as for the oscillator, the 1st Doubler is tracked for alignment shown in Fig. 34. The following procedure should be used for bending the plates. If the scope trace is high on the right side, as shown in Fig. 35A, the capacitance is too high, and rotor plates should be bent away from stator plates. If the scope trace is low on right side, as shown in Fig. 35B, the capacitance must be increased by decreasing spacing between plates.

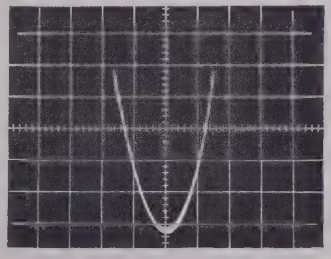
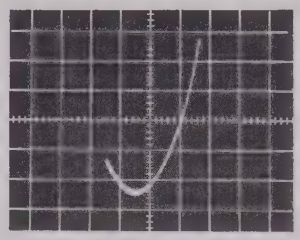
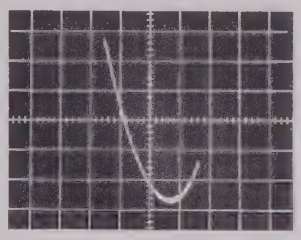


Figure 34. Doubler Tracking — Doubler Resonance Centered on Oscillator Frequency



(A) Frequency of Doubler Too Low

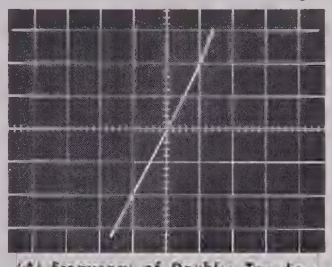


(B) Frequency of Doubler Too High

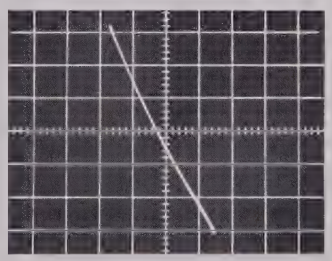
Figure 35. Doubler Tracking — Doubler Resonance within Limits of Center of

On initial check, the capacitance might be extremely far off. In this case, the scope trace will appear as shown in Fig. 36A and B.

Tracking of the 1st Doubler should be within 150 kc of center frequency.



(A) Frequency of Doubler Too Low



(B) Frequency of Doubler Too High

Figure 36. Doubler Tracking — Doubler Resonance Out of Limits of Center of Oscillator Frequency

**This adjustment would not be required in touch-up alignment and is to be used only when specific part indicated in the procedure is replaced.

Fig. 35A and B shows, pictorially, the indication of the limits.

2ND DOUBLER ALIGNMENT

The 2nd Doubler is aligned visually with an oscilloscope in the manner described under 1st Doubler alignment.

Preliminary Setup

The oscilloscope is connected to Pin No. 2 of J100. Before alignment of this stage, the output coil and attenuator must be checked for physical location with respect to each other. Fig. 37 shows the output coil (L106) and the attenuator loop (L107). The 2nd Doubler is aligned with 300 kc deviation modulated at 50 cps.

Alignment

1. Starting at 270 mc, the capacitor C122 is adjusted for center of resonant curve to fall on the oscillator frequency. (Refer to scope patterns for 1st Doubler alignment, Fig. 34 through 36.)

2. At 260 mc, the stator plate segments are adjusted for tracking the same as for the 1st Doubler. Refer to scope patterns indicated.**

NOTE: While checking doubler alignment, watch for signs of jitter in trace, especially when changing frequency. Jitter is an indication of poor rotor wiper contact. Clean wipers and readjust, making sure that no lubrication is present.

The RF Unit is re-installed in the instrument as per information under Mechanical Disassembly RF Unit. Do not assemble cover to unit.

Calibration Check

EQUIPMENT REQUIRED

hp 5243L Electronic Counter and 5253A Frequency Converter or Equivalent.*

Frequency Dial Calibration Check

Align 202J frequency dial on shaft so calibration every 5 mc, falls within ±0.5% as read on frequency counter.

Piston Attenuator

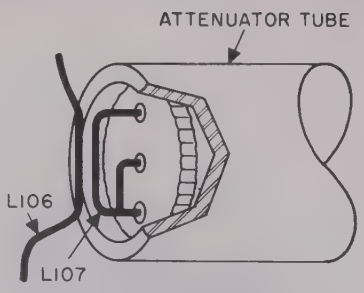
EQUIPMENT REQUIRED

hp 431A Power Meter or equivalent.*

PISTON ATTENUATOR CALIBRATION

Preliminary Setup

Position the attenuator piston so that the pickup loop is approximately one-half wire diameter out of the tube. The pickup loop and output coil should be parallel (Fig. 37). The upper limit stop should be set with the pickup loop in this position. Connect the Power Meter to the 202J RF Output jack. Set frequency to 195 mc and apply power to instrument.



rigure 37. Output Coil-Physical Location

Adjustment

1. Adjust attenuator dial on shaft to indicate 100K μv at upper limit stop.
2. Adjust RF control to read 100K μv (0.2 mw) on Power Meter.

3. Adjust RF Meter Adj (R300) and RF control for "red-line" indication with 0.2 mw on Power Meter.

4. Continue Step 3 until "red-line" indication of RF Monitor meter indicates 100K μv (0.2 mw) as read on Power Meter and attenuator dial.

5. Rotate attenuator to read 50K μv. Reading on Power Meter should be 0.050 mw ±.84db.

6. Check 200K μv attenuator setting. Power Meter should read 0.80 mw ±1.68 db.

NOTE: If the spread between 50K μv and 200K μv is too large, the stop on the high limit must be reset to move the pickup loop away from the output coil at the 100K μv setting of the attenuator dial. When stop is readjusted, repeat steps 2, 3, and 4.

7. Check attenuator output calibration at 10 mc increments for 100K μv and 50K μv settings of the attenuator dial. Use RF control to set meter to "red line" at each frequency if AGC is not set properly at this point.

8. If the RF Monitor Meter cannot be set to "red line" with R300 (RF Meter Adj.), the position of the output coil will have to be changed.

NOTE: Adjustments to the output coil will change its inductance and therefore disturb the tracking of the output (2nd Doubler) stage. The rotor plates will not need readjusting because the output stage can be repeaked by using the trimmer capacitor. Using the set-up for 2nd Doubler tracking, adjust the trimmer capacitor to center the tracking on the carrier frequency.

9. If the RF Monitor Meter is above "red line" when the Power Meter and the attenuator dial indicate the same output, and the meter cannot be adjusted with R300 (RF Meter Adj.), move the 2nd doubler coil closer to the attenuator.

10. If the RF meter is below "red line" and cannot be adjusted with R300, move the 2nd doubler coil back away from the attenuator.

AGC Circuitry

EQUIPMENT REQUIRED

hp 412A dc VTVM or equivalent.*

AGC ADJUSTMENT

Preliminary Setup

At 195 mc, with attenuator set at 100K μv, apply power to instrument. Connect dc VTVM to pin No. 2 of J100.

Adjustment

1. Set RF control to "red line" on meter and read the negative dc voltage. This is the diode detector output.

2. Reconnect dc VTVM to measure negative dc voltage at pin No. 1 (cathode) of V300 (6AW8).

3. Using RF control, adjust voltage on pin No. 1 of V300 (step 2) to be 0.5 v *less negative* than the voltage on pin No. 2 of J100 (step 1).

4. Adjust AGC BIAS ADJ (R308) for RF Monitor meter "red line".

5. RF Monitor meter should stay within "red line" for entire range of frequencies and range of output of 202J

△F Circuitry

EQUIPMENT REQUIRED

5243L Electronic Counter and 5253A converter or equivalent.*

Preliminary Setup

Connect 202J directly to counter.

Adjustment

1. Set △F KC to —30 kc and note reading on counter.

2. Set △F KC to +30 kc. Adjust △F Adj (R419) for reading of 60 kc ± 7 kc as read on counter.

3. Repeat steps 1 and 2 until △F KC control is within 60 kc ± 7 kc for the dial calibration of —30 kc to +30 kc as read on frequency counter.

*See Recommended Equipment List under Adjustment and Calibration.

**This adjustment would not be required in touch-up alignment and is to be used only when specific part indicated in the procedure is replaced.

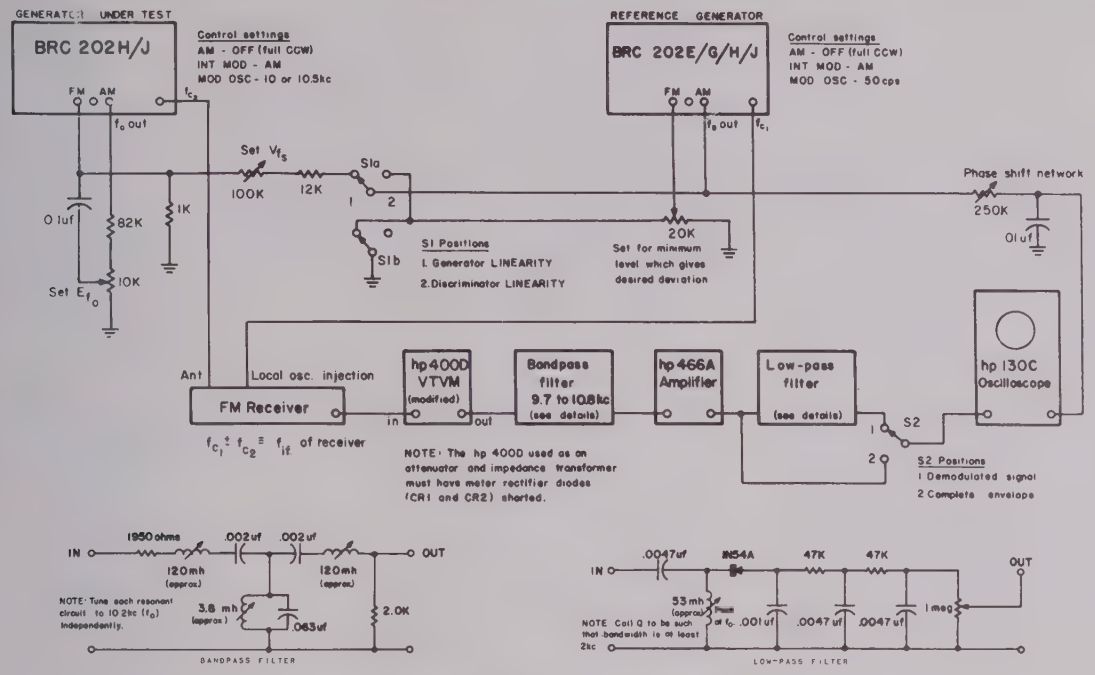


Figure 38. Setup for FM Linearity Measurement

Generator FM Linearity

The term "linearity" as used in this measurement procedure, is actually the percent change in slope of the FM transfer characteristic from a straight line. This measurement is described in detail under "Additional Information for FM Measurements."

EQUIPMENT REQUIRED

1. BRC 202J or equivalent. *
2. FM Receiver.
3. hp 400D or equivalent (modified—see Fig. 38). *
4. hp 466A Amplifier or equivalent. *
5. hp 130C Oscilloscope or equivalent. *
6. Bandpass Filter. (See Fig. 38 for details).
7. Low-pass Filter (See Fig. 38 for details).
8. Miscellaneous Electrical Components (See Fig. 38 for details).
   a. 10K Potentiometer
   b. 20K Potentiometer
   c. 100K Potentiometer
   d. 250K Potentiometer
   e. 1K Resistor
   f. 12K Resistor
   g. 82K Resistor
   h. .01 μf Capacitor
   i. 0.1 μf Capacitor
   j. DPST Switch
   k. SPST Switch

Measurement Procedure

1. Connect equipment as shown in Fig. 38.
2. Control settings on generators:

Control	*Generator Under Test*	*Reference Generator*
AM	OFF (Full CCW)	OFF (Full CW)
INT MOD Switch	OFF	AM
FREQ CPS	10.5 kc	50 cps
DEV KC	300	300 or 240
MOD METER Switch	FM	FM
Attenuator	0.1 v	0.2 v
RF Monitor Meter	"Red Line"	"Red Line'
FM	Full CW	Full CW
△F KC	O (Arrow Vertical)	O (Arrow Vertical)
FREQUENCY MC	Difference in frequency between two generators should be IF of FM Receiver.	

3. Turn switch S1 to the discriminator position (Position 2).
4. Adjust 20K ohm potentiometer for approximately 160 kc deviation on the reference generator Modulation Meter. Then, using the FM control on the reference generator, set the Modulation Meter at 150 kc deviation.
5. Set the reference generator INT MOD switch to off and the test generator INT MOD switch to AM.
6. Adjust the "Set E_{f_o}" control for 15 kc deviation on the Modulation Meter (generator under test).
7. Set the test generator INT MOD switch to the off position and the reference generator INT MOD switch to the AM position. Set Switch S1 in the generator position (Position 1).

*See Recommended Equipment List under Adjustment and Calibration.

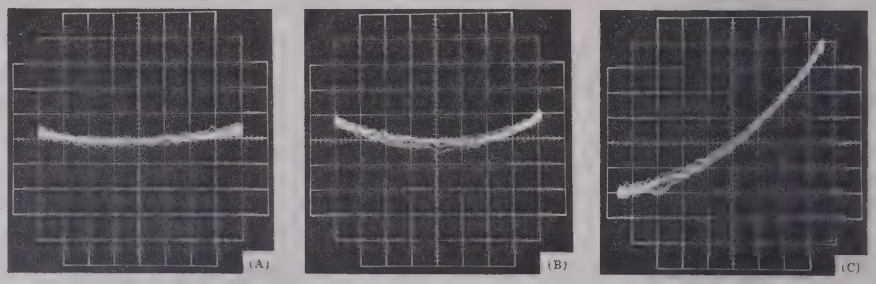
8. Adjust "Set V_{f_s}" control for 150 kc deviation on Modulation Meter (test generator). 150 kc deviation can be set precisely at this point by making a Bessel Zero calibration and observing the output of the receiver on the 400D in Fig. 37. (Diodes are not shorted.) Make sure the reference generator and test generator INT MOD Switches are OFF. The modulation signal (27.173 kc) is fed into the FM terminals of the generator under test.

NOTE: This technique can be used instead of the transfer oscillator method to set the deviation rotor plates. After making a Bessel Zero calibration, use a 400 cps and modulation signal to adjust the rotor plate to give a constant meter reading on the 400D.

9. Set the INT MOD switch in the generator under test to AM.

10. For FM demodulators of high output impedance, an (HP 400D, etc.) should be used to provide high input and low output impedance and some attenuation (in 10 db steps). Many telemetry receivers have cathode followers or other low impedance outputs which will drive the 4K bandpass filter impedance adequately. The range switch on the 400D has to be set to give an on-scale reading. However, to avoid nonlinearity, the meter diodes in the 400D have to be shorted for the measurement. Therefore, it will be necessary to set the range switch of the meter before the diodes are shorted, or use another meter to determine the output of the receiver, and set the range switch accordingly.

11. Set switches S1 and S2 to Position 2 (Discriminator Linearity and Complete Envelope position). Adjust the reference generator frequency for a symmetrical envelope. This indicates that the IF of the signal matches that of the receiver. The phase shift control is now adjusted to give a clean envelope or a single line trace (See Fig. 39). The vertical scope gain is adjusted so that the full envelope covers 10 cm. Increase the scope gain 10 times so that 1 cm represents ± 1% nonlinearity. If the scope gain can be increased 20 times without overloading, 1 cm represents ± .5%. When using the AM demodulator and low-pass filter, put S2 in position 1 (demodulated signal) and the scope gain can be increased 20 times.



Discriminator Only — *Discriminator and Signal Generator* — *Incorrectly Adjusted Reactance Tube Bias*

Figure 39. Typical Change of Slope During Linearity Measurement

NOTE: Should a suitable oscilloscope, such as the HP 130C, be available, the refinement of the amplitude demodulator and the nf, low-pass filter may not be needed. The nonlinearity measurements are read directly from the scope trace (either the complete envelope or the AM demodulated trace). See Fig. 39 for AM demodulated trace.

12. Adjust the reference generator frequency for a symmetrical trace. At this time, check to see that the system is not being overloaded. A 2 to 1 change in RF output for either generator should not make a significant change in the scope trace. RF level adjustment may be necessary to satisfy this condition, depending on the receiver used.

13. Read the nonlinearity of the receiver on the scope. Nonlinearity measurements are read peak-to-peak, minus the width of the trace which may show noise. Set switch S1 to Position #1 (Generator Linearity) and read nonlinearity (peak-to-peak). The difference between the two readings is the generator nonlinearity. It is in this position that the reactance tube bias adjustment (R107) is set. Check nonlinearity across the frequency range when making this adjustment.

Deviation Measurement

The following procedure is for adjusting the deviation rotor plate and the FM Mod Meter.

EQUIPMENT REQUIRED

1. hp 540B Transfer Oscillator or equivalent.*
2. hp 5243L Electronic Counter or equivalent.*
3. hp 5253A Frequency Converter for Electronic Counter.*
4. hp 130C Oscilloscope or equivalent.*
5. hp 650A Test Oscillator or equivalent.*

Preliminary Setup

1. Connect equipment as shown in Fig. 40.
2. Set the 202J Generator controls as follows:

Control	*Setting*
Frequency Megacycles	195 mc
Mod Meter Switch	FM
INT MOD Switch	OFF
AM Control	Full CCW
Dev KC Switch	300 kc

3. Set the Test Oscillator to 400 cps with approximately 2 volts output.

*See Recommended Equipment List under Adjustment and Calibration.

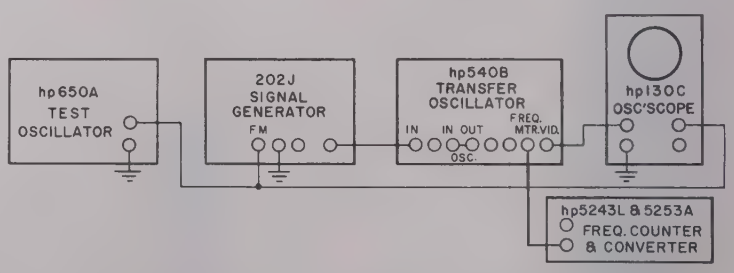


Figure 40. Setup for Deviation Measurement

Measurement

1. Adjust FM control on 202J to give 150 kc deviation (Fine adjustment can be made with the output control on the test oscillator.) as indicated by the transfer oscillator method. (See operating manual for transfer oscillator.)
2. Adjust R612 (Mod Meter Adj) to indicate "150 kc" deviation on Modulation Meter. For the balance of this measurement the 400 cps amplitude should not be changed by the test oscillator output control or FM control on the 202J.
3. The 202J Signal Generator should indicate nominally "150 kc" deviation across the band. Checks may be made at 10 mc increments.
4. At each check point (10 mc increments) the deviation rotor plate may be adjusted to give 150 kc deviation consistantly across the band. This segmented plate is adjusted in the same manner as the rotor plates during RF alignment. At the 10 mc increments the plate is adjusted to give a nominal reading of 150 kc by the Transfer Oscillator method. If the deviation is greater than 150 kc, increase the rotor capacitance by decreasing the plate spacing of the segmented plate just going into mesh. If the deviation is less than 150 kc, decrease the rotor capacitance by increasing the plate spacing of the segmented plate just going into mesh. By special care during this procedure, the modulation can be set well within the specifications shown in Section II.

Fidelity Measurement

Refer to "Additional Information for FM Measurement"—FM Deviation and Fidelity Measurement.

ADDITIONAL INFORMATION FOR FM MEASUREMENTS

Measuring FM Linearity

What do we really mean by "nonlinearity", and the distortion which results therefrom? Nonlinearity refers to that charateristic of a circuit which causes the output to be related to the input by other than a straight line function. As a result, the circuit may not be specified by linear differential equations with time as the independent variable. Many terms are used to describe distortion due to this concept of nonlinearity.

Nonlinear Distortion has been defined by the IRE Standards on Circuits as "Distortion caused by a deviation from a desired linear relationship between specified measures of the output and input of a system". The related measures need not be output and input values of the same quantity; e.g., in a linear detector, the desired relation is between the output signal voltage and the input modulation envelope. There are specific means of measuring nonlinearity among which are *Total Percent Harmonic Distortion* and *Intermodulation Distortion.* It may be felt that, somehow, there is a large difference between intermodulation distortion (IM) and total percent harmonic distortion (HD). While there may be advantages in one system of measurement or the other, it should be remembered that finite results in either an IM or HD measurement occur due to nonlinearity of the transfer characteristic, and measurement by either method may be analytically related for any specific shape of curve.

NONLINEARITY MEASUREMENT TECHNIQUES

In the simple case of amplitude modulation, it is possible, by means of a suitable wave analyzer, to measure the frequency spectrum resulting from the modulation process. If the modulation signal is free of distortion and the modulation process is perfectly linear, the resulting spectrum in the vicinity of the carrier will contain only the carrier and the two sidebands, separated from the carrier by the modulation frequency as seen in Fig. 41A. If nonlinearity of the transfer characteristic exists, the results may be as shown in Fig. 41B. Here, the appearance of sidebands, separated from the carrier by integral multiples of the modulating frequency, is not only qualitative evidence of nonlinear distortion, but affords a measure of this distortion if the amplitudes of all the sidebands relative to the carrier are determined.

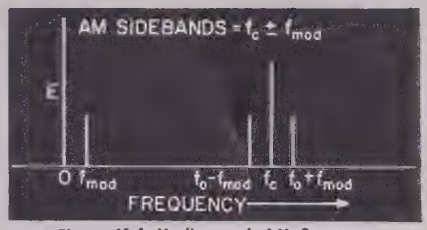


Figure 41A. Undistorted AM Spectrum

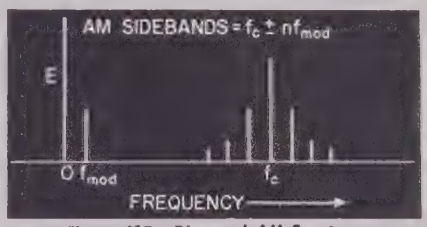


Figure 41B. Distorted AM Spectrum

In the FM case, for deviations and modulation frequencies for which the modulation indices, defined as

$$m = \frac{\text{peak deviation}}{\text{modulating frequency}},$$ are appreciably greater than unity (the usual case), the resulting frequency spectrum becomes exceedingly complex, even for an undistorted modulation process. In the presence of nonlinearity of the frequency modulator, the spectrum becomes even more complex; thus ruling out spectrum analysis as a simple means of measuring nonlinearity.

A second method for measuring a frequency modulator transfer characteristic is possible, if the modulator is capable of operation at dc. This method consists of introducing a known increment of modulating voltage and measuring the resulting frequency increment. Its precision is limited by the stability of the carrier frequency in the absence of modulation and the ability to read small increments in voltage and frequency precisely. Modern measuring equipment has solved the latter two problems, but not the former.

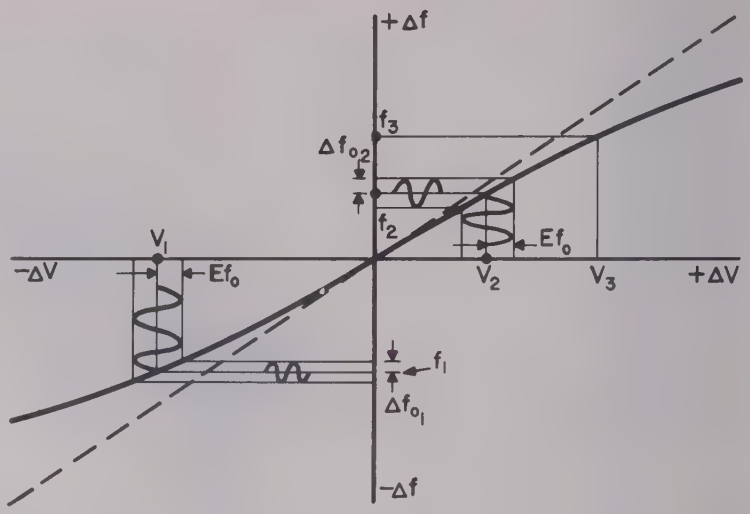
In addition to the matter of precision, it is desired to be able to make adjustments on the frequency modulator for minimum nonlinearity as a result of an instantaneous display of nonlinearity of the frequency modulator.

New FM Linearity Measurement Method

In order to best understand the method to be described, let us resort to a general discussion of a circuit which relates a change in voltage to a change in frequency or vice versa. This covers the general case of frequency modulators and demodulators. Reference to Fig. 42 will show the transfer characteristic of such a circuit. The horizontal axis represents changes in voltage and the vertical axis changes in frequency. Shown dotted is a reference straight line which passes through the origin, as does the arbitrary nonlinear curve. The problem is to measure the departure of the actual curve from the ideal straight line. Here, the reference straight line chosen is that line for which the rms sum of the differences between the actual curve ordinates and the straight line ordinates is a minimum.

Fig. 42 shows that one way to describe the departure of the curve from the straight line is to measure a large number of individual ordinates of the actual curve, subtract them from the ordinates of the straight line, and report the differences in tabular or curve form. This technique is not instantaneous, even when automated.

It is also evident in Fig. 42 that if the slope of the actual curve could be compared, at any point, with that of the straight line, a relationship covering the nonlinearity could be readily developed. Thus, it should be possible to make an incremental measure of the slope of the curve by introducing a small amplitude sine wave of voltage, E_{f_o}, superimposed on a direct voltage. The direct voltage may then be varied. If the resulting frequency variation, due to the small constant amplitude search voltage, E_{f_o}, were measured at each value of V, and plotted as a function of V over the entire range of interest of the voltage axis, a plot of the varying slope of the actual transfer characteristic would result. The extent to which this departs from the slope of the straight line, is a measure of the nonlinearity of the transfer characteristic. This can be done dynamically by allowing V to vary over the desired dynamic range at a sinusoidal rate, f_s. The slope of the transfer characteristic can be plotted on an oscilloscope by driving the vertical axis with an amplitude proportional to Δf_o and the horizontal axis with a voltage proportional to V, and varying at rate f_s.



Definition of Terms

E_{f_o} = Constant Amplitude "Search" Voltage

$V_1; V_2; \cdots V_k$ = Arbitrarily Chosen Operating Points

Δf_{o_k} = Frequency Deviation at Rate f_o and at Operating Point V_k

K_k = Slope of Solid Curve at any Point k

$\Delta f_{o_k} = K_k \cdot E_{f_o}$

As $E_{f_o} \rightarrow 0$; $\dfrac{\Delta f_{o_k}}{E_{f_{o_k}}} \rightarrow \dfrac{df}{dE}$

Figure 42. Transfer Characteristic with Typical Nonlinearity

Consider the case of a linear frequency modulator and frequency demodulator, to which the two test voltages, E_{f_o} and V_{f_s}, are applied with the understanding that V_{f_s} is of such magnitude as to sweep through the entire dynamic range of interest, and that E_{f_o} is very much smaller than V_{f_s}, typically one-tenth as great. This situation is shown in Fig. 43.

As might be expected, the output spectrum of the linear demodulator driven by the linear modulator is simply E_{f_o} and V_{f_s}, with the amplitude relationship established by the input. Now, assume that the frequency modulator is linear, but that the frequency demodulator is nonlinear (curve of the nature shown in Fig. 42. If E_{f_o} were to be plotted as a function of V_{f_s}, it would approximately plot the slope of the transfer characteristic being studied, namely, that of the assumed nonlinear demodulator. Therefore,

$$\Delta f_o = \frac{df}{dV} \ (E_{f_o}),$$

where df/dV is recognized as the slope of the transfer characteristic in Fig. 42.

Another view of the same phenomena is shown in Fig. 43B. This shows the output spectrum of the nonlinear demodulator driven by the linear modulator, and with the input as assumed previously. The output spectrum is now far more complicated than in the linear case (Fig. 43A), consisting not only of V_{f_s} and E_{f_o}, but also of integral multiples with decreasing amplitude of both f_s and f_o, and sum and difference frequency terms resulting from the nonlinearity of the transfer characteristic.

Fig. 43C shows the df/dV curve as determined by plotting the amplitude of Δf from the demodulated output as a function of V_{f_s}. This would be an accurate plot of the transfer characteristic slope if the magnitude of E_{f_o} in the input were made vanishingly small compared to V_{f_s}. This approximation is entirely satisfactory if $V_{f_s}/E_{f_o} \approx 10$. It should be emphasized that Fig. 43C and

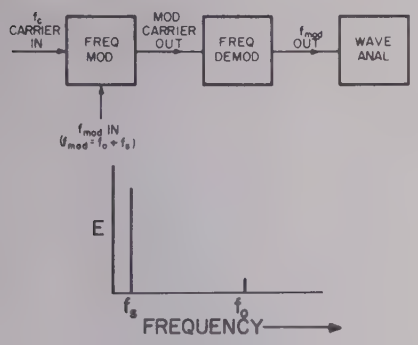


Figure 43A. Linear AM and FM Demodulator with Output Spectrum

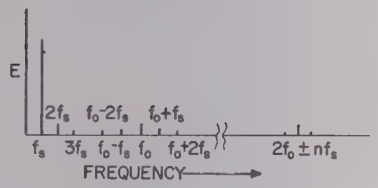


Figure 43B. Nonlinear FM Demodulator — Linear FM Modulator Spectrum

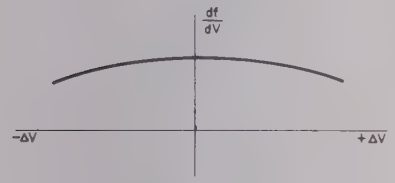


Figure 43C. Plot of df/dV of Figure 42

the spectrum plot of Fig. 43B contain the same information concerning the transfer characteristic nonlinearity, but displayed in a different manner. The question now is, how may a simple display be achieved?

The block diagram of Fig. 44 shows the introduction of a bandpass filter which accepts f_o and the significant sidebands about it due to f_s, and the display of the resulting carrier envelope on the vertical axis of an oscilloscope. The horizontal axis is driven by the initiating V_{f_s} from the input of the frequency modulator. Fig. 45 shows a typical result. Since the demodulated signal is passed through a bandpass filter, the upper and lower section of the envelope presented to the oscilloscope must be symmetrical; therefore, either may be selected for consideration. Where the amplitude of the f_s sidebands about f_o is very low, as would be true of a highly linear circuit, the resulting departure of the oscilloscope trace from a rectangle is small. Ignoring half the envelope, it is possible to offset the centering of the oscilloscope

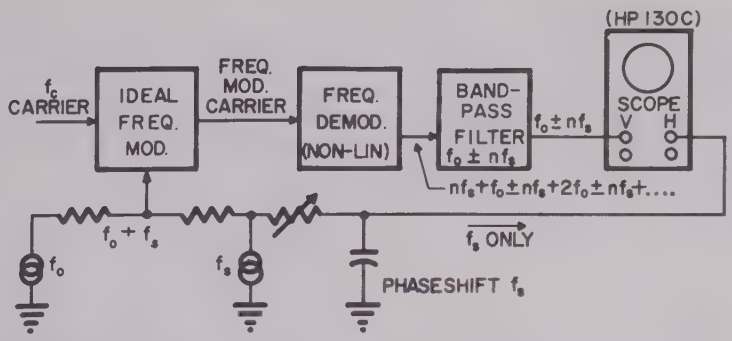


Figure 44. Block diagram of Circuit Used to Provide Instantaneous Display of Transfer Characteristic Change of Slope

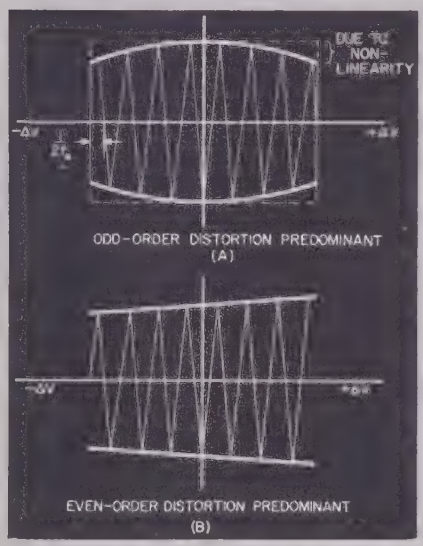


Figure 45. Typical Display from Circuit in Figure 44.

and greatly expand either half of the display. This permits measuring changes in slope down to about 0.1% of one-half the envelope.

The departure of the envelope in this display from a reference value (chosen as the slope at the origin of Fig. 42, and appearing on the vertical center line of the oscilloscope displays in Fig. 45), is a direct measure of the change in slope of the transfer characteristic. Therefore, the slope of this curve is approximately the second derivative of the transfer characteristic. If the envelope shows symmetry about the vertical center line of the trace (Fig. 45A), it can be shown that this is a result of odd-order harmonic distortion. If the envelope is asymmetrical about the vertical center line, and has mirror image symmetry about the horizontal center line (Fig. 45B), the distortion is largely even-order. Thus, it can be seen, that much information is contained in the displays of Fig. 45, produced by the circuit of Fig. 44.

Up to this point a linear modulator has been assumed. Where is the perfectly linear modulator available? The technique illustrated in the block diagram of Fig. 46 shows a method of "synthesizing" an FM signal, modulated simultaneously by two frequencies (f_o and f_s), in which sidebands of f_s around f_o are not produced, even though the individual signal generators have some nonlinear distortion. The technique used is the receiver practice of mixing an incoming signal with a local oscillator and amplifying at a fixed intermediate frequency before frequency demodulation is performed. Then, consider the linearly demodulated spectrum produced by modulating either signal generator by a single frequency, remembering that one generator is modulated by f_s and the other by f_o. The output spectrum from a perfect demodulator, driven by a nonlinear modulator with single frequency input, would consist of the original modulating frequency and integral multiples of this frequency, generally in decreasing magnitude. Since the two frequencies f_s and f_o do not

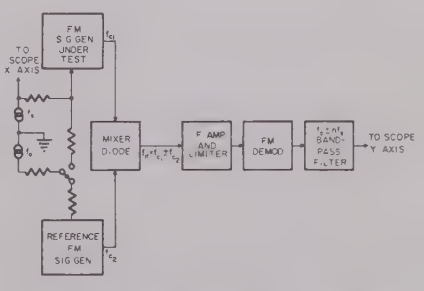


Figure 46. Block Diagram of Circuit for Synthesizing Perfectly Linear Modulation

Figure 47. Demodulator Output Spectrum of nf_s and nf_o with Superimposed Bandpass Filter — Linear Case

simultaneously exist in either frequency modulator, it is not possible to produce sum and difference frequencies in the linearly demodulated output. (See Fig. 47). When the carrier frequencies (f_{c_1} and f_{c_2}) generated by the two FM sources (one modulated by f_s and the other by f_o) are mixed at RF (Fig. 46), and the difference carrier frequency is amplified by a suitable selective amplifier, the instantaneous frequency in the selective amplifier is the simple arithmetic difference of the instantaneous frequency modulated sources. Thus, no sum and difference frequencies of the modulating signals f_o and f_s appear in the FM signal at average frequency, f_{if}.

Now, introduce a bandpass filter centered on f_o in the output of the demodulator. The bandwidth of this filter must be wide enough to accept the significant sidebands of f_s about f_o. It has been found that acceptance of sidebands up to the 3rd is sufficient. This bandpass is shown by dotted lines in Fig. 47. It will be seen that this filter eliminates f_s and all of the distortion products due to the nonlinearity of the frequency modulators in the individual signal generators which produce the difference frequency, f_{if}.

Now, consider the effect of nonlinearity in the frequency *demodulator* when driven by a signal generated by the circuit of Fig. 46. It is evident that the spectrum will consist not only of the components shown in Fig. 47, but of sidebands about f_o and its harmonics spaced by nf_s. (See Fig. 48.) If the output of the bandpass filter is connected to an oscilloscope, an envelope, similar to that of Fig. 45, will be seen. Thus, a technique is available for using two signal generators of finite modulator nonlinearity to synthesize an apparently distortionless signal which may then be used to measure the nonlinearity in a frequency demodulator.

To avoid the necessity of offsetting the axis of the oscilloscope display and expanding the scale to look at small deviations of the envelope from rectalinearity, it is possible to eliminate the carrier with a linear amplitude demodulator. The composite block diagram of Fig. 49 shows the application of a simple linear AM detector followed by a low-pass filter to eliminate the carrier, f_o, from the display. The output from the linear detector will be a direct current component proportional to the peak amplitude of f_o, together with the envelope produced by the nf_s sidebands beating with the carrier. The percentage change in slope, compared to a straight line, may be read by expressing the peak value of the demodulated envelope as a percentage of the dc component (which is proportional to the peak value of f_o).

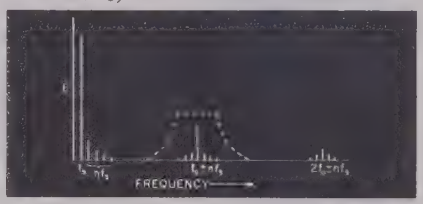


Figure 48. Demodulator Output Spectrum of nf_s and nf_o Including nf_s Sidebands About f_o — Nonlinear Case

If the output of the AM detector and nf_s low-pass filter is read on an averaging meter, an average value of the percent change in slope will be read. The amplitude of the significant harmonics (2nd and 3rd) of f_s usually has been relatively low, so the value read by an rms calibrated, average reading meter closely approxmates the rms value of the departure of the slope of the transfer characteristic from the constant slope of the ideal straight line. Since the departure of the transfer characteristic of Fig. 42 from a straight line necessitates a change in the slope of the transfer characteristic, it is seen that these are related effects. Calculations have shown that the numerical values for percent change in slope are always less than the values for percent departure of the transfer characteristic from a straight line. The specific relationship depends on the actual shape of the curve, however, for transfer characteristics experienced in FM modulators and demodulators. The ratio of percent departure from a straight line to percent change in slope from that of a straight line varies from 1/2 to 1/3. Thus, a measurement of 1% change in slope insures a departure of the transfer characteristic from a straight line of less than 1%.

Fig. 49 shows a composite block diagram of the entire setup with a few additional features. Instead of separately modulating the signal generator under test and the reference signal generator with f_s and f_o respectively, if the signal generator under test is simultaneously modulated by f_s and f_o (by switching S_1) the change in slope of the frequency modulator of the signal generator under test will be superimposed upon that of the FM demodulator. Thus, if the individual ordinates of the display produced by the block diagram in Fig. 49 are noted for the case of separate modulation, and then determined for the case of simultaneous modulation of the signal generator under test, the algebraic difference of these ordinates will produce a curve which is due to the nonlinearity of the FM signal generator under test only, and does not depend upon that of the frequency demodulator. Note that when

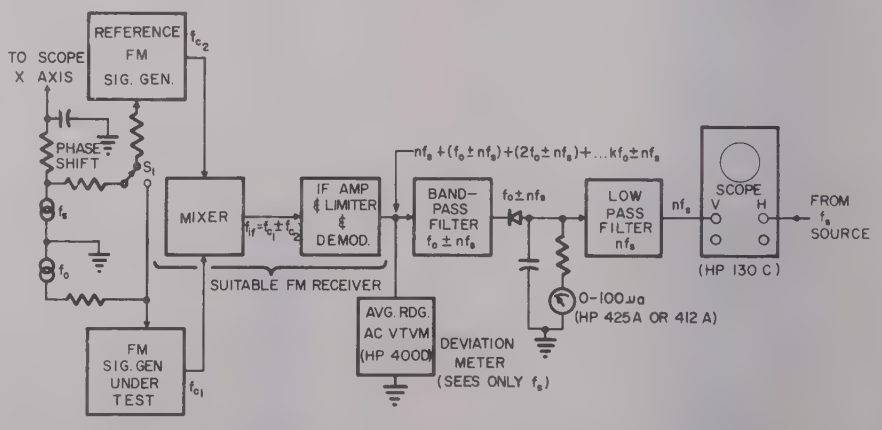


Figure 49. Block Diagram of Circuit Used to Obtain Change of Slope Display

switching f_s from one generator to the other, the horizontal polarity of the display is reversed.

Thus, a circuit and measuring technique have been developed which will measure the change in slope of a frequency modulator largely independently of the demodulator, as well as the change in slope of the demodulator independently of the frequency modulator.

Measuring Frequency Deviation and Fidelity

There are in use today several methods of measuring the frequency deviation of a frequency modulated signal. However, there is one method which is both straight forward and accurate, requiring the use of commonly available laboratory equipment. This method is known by various names, probably the most used of which is "The Bessel Zero Method". As this name implies, it is related to the Bessel functions, the zero-order Bessel function J_0 in particular. The fact that the zero-order function passes through zero amplitude at certain points, which correspond to discrete modulation indices, forms the useful basis for the method, a heterodyne type receiver is tuned to the unmodulated carrier frequency of the source to be tested so that a beat frequency of some several hundred cycles is obtained, which can be monitored with earphones or a voltmeter. As a carrier is frequency modulated by a single frequency, the beat frequency will be observed to disappear at several points as the amplitude of the modulating signal is increased. As previously stated, these null points correspond to specific modulation indices, the first five of which are:

2.4048
5.5201
8.6537
11.7915
14.9309

These five points are graphically illustrated by the curve of the zero-order Bessel function in Fig. 50. The modulation index being the ratio of frequency deviation to modulating frequency, it becomes apparent that knowing the indices at which the carrier is zero and knowing the modulating frequency, the frequency deviation at each carrier zero is readily determined.

As an illustration, let us take a value of 10,000 cps for the modulating frequency. As the amplitude of the modu-

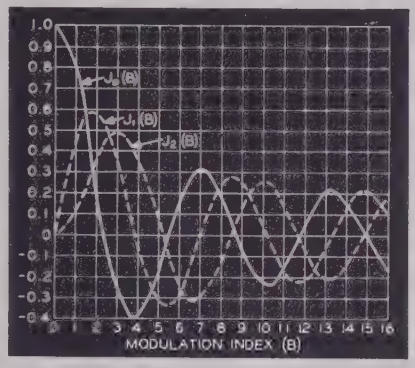


Figure 50. Bessel Functions of the First Kind

lating signal is increased, nulls will be obtained at the deviations of 24.1, 55.2, 86.5, 117.9 and 149.3 kc.

It is well to bear in mind that in order to perform this test with any degree of success, it is necessary that the modulating frequency be considerably greater than the beat frequency being monitored. This is so because the sidebands of a frequency modulated signal are spaced at intervals equal to the modulating frequency (see Fig. 51). If such is not the case and the ratio of modulating frequency to beat frequency is, for an extreme case, only of the order of 2 to 1, the possibility exists of beating with the first side-band frequency rather than the carrier. If unknown to the operator this will produce erroneous results, since the side-bands, like the carrier, pass through points of zero amplitude at particular modulation indices (see Fig. 50).

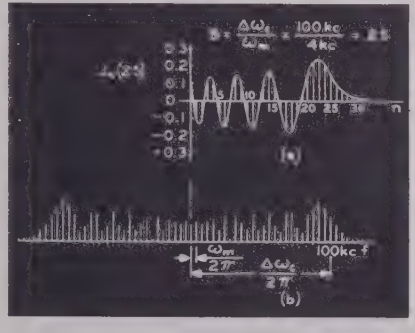


Figure 51. Bessel Functions and Frequency Spectrum for f_m=4kc and Δf_c=100kc

The accuracy to be expected from this method is dependent upon the accuracy of the modulating frequency and how well the nulls can be defined. For example, let us assign a value of ±0.5% as the accuracy of the modulating frequency. Holding the modulation index constant, this ±0.5% is applied directly to the frequency deviation. Further, let us assume that the sensitivity of our system is such that the smallest amplitude beat-frequency we can detect is 40 db below the beat-frequency signal due to the unmodulated carrier. Because the receiver signal amplitude remains constant, the amplitude of the beat frequency varies directly as the amplitude of the carrier frequency of the source under test. If we arbitrarily assign a value of 1 to the amplitude of the beat-frequency due to the unmodulated carrier, we may interpolate directly from a table of zero-order Bessel functions to determine the definition of the nulls. Now, 40 db below 1 is 0.01, which we can locate in the table in the vicinity of the first zero point. If what we believe to be 0 is actually 0.01, then the modulation index we obtain is approximately 2.38 instead of 2.4048, or an error of about 1.0%, which if the Bessel curve is assumed linear in the vicinity of zero, it is possible on either side of zero, or ±1.0%. For this case, if we hold the modulating frequency constant, this error too is applied directly to the deviation frequency. Taking both errors into account, for this example the maximum possible error in determining the deviation frequency at a modulation index of 2.4048 is ±1.5%. Because the slope of the zero-order Bessel curve decreases as it passes through zero at higher modulation indices, the maximum possible error in determining frequency devation will increase slightly with higher modulation indices.

The minimum receiver bandwidth that can be used with VHF FM generator of good stability limits the modulation frequency to a minimum of about 5 cps. This puts a limit of approximately 12 kc on the minimum deviation that can be measured by Bessel nulls. On the other hand, nulls above the 4th order become difficult to identify and precisely locate. This limitation is not serious because most Signal Generators and FM telemetry receivers are quite flat from 50 cps to 15 kc. The Bessel Null method fails, and hence a problem arises in measuring FM fidelity at small modulation indices when modulation frequencies of 10 kc to several megacycles are used at relatively small deviations. For instance, a deviation of 50 kc at a modulating frequency of 500 kc gives a modulation index of 0.1.

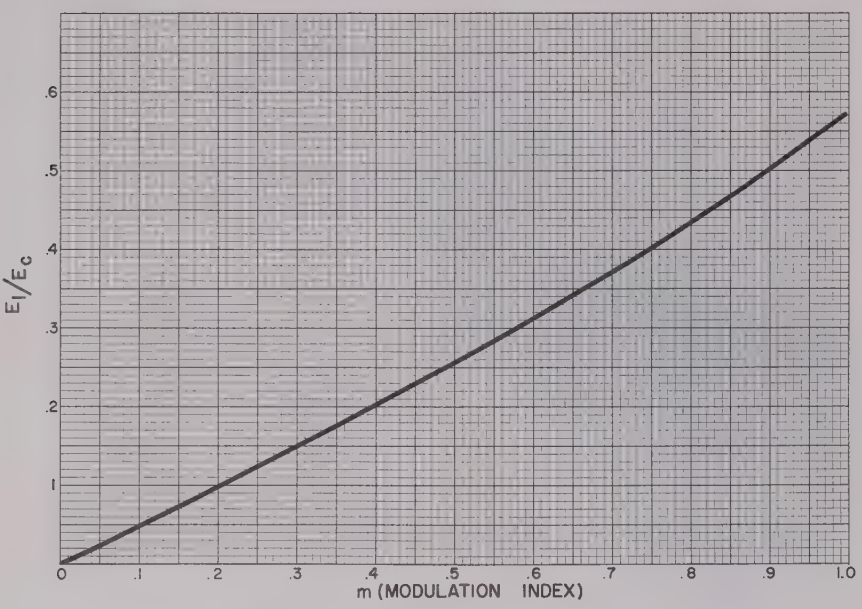


Figure 52. Amplitude Ratio — m vs. E_1/E_c

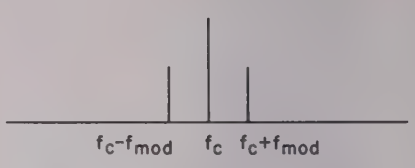


Figure 53A. Undistorted FM Spectrum

Figure 53B. AM Distorting Spectrum

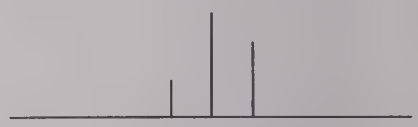


Figure 53C. FM Spectrum with Effect of AM

Since the first order Bessel null appears at m = 2.4048, that is the minimum value of "m" useable with the Bessel null method. A ratio measurement of sideband to carrier amplitudes fills this gap. This ratio E_1/E_c equals $J_1(m)/J_o(m)$ because $E_1 = E_oJ_1(m)$ and $E_c = E_o J_o(m)$.

The carrier amplitude $E_c = E_o J_o(m)$, the first order side-band amplitude $E_o = E_oJ_1(m)$, and the nth order sidband amplitude $E_n = E_o J_n(m)$ where E_o is the amplitude of the unmodulated carrier. The ratio under consideration is E_1/E_c. This equals the Bessel Function ratio $J_1(m)/J_o(m)$, which in turn is a function of the modulation index (m). Therefore since f_{mod} is known and "m" can be determined from E_1/E_c, the actual deviation can be calculated. E_1/E_c equals $J_1(m)/J_o(m)$. If $J_1(m)/J_o(m)$ is known "m" can be found in any table of Bessel functions of the first kind (See Fig. 50). For convenience m vs. $J_1(m)/J_o(m)$ is plotted in Fig. 52. The values of $J_1(m)/J_o(m)$ or E_1/E_c for some of the more common modulation indices are listed in Table I.

For the sideband method to give accurate results, the FM spectrum cannot be distorted by AM. Residual AM on an FM spectrum increases the amplitude of one sideband and decreases the amplitude of the other as shown in Fig. 53.

An amplitude sideband measurement set up which eliminates the need for a receiver of known fidelity is shown in Fig. 54 and Fig. 55. By operating the Signal Generator under test at 0.2v output and the beating generator at 0.1v (through the series R in the mixer), the amplitude of the intermediate frequency, f_{if}, going into the receiver is limited, removing any AM. This presents a nearly pure FM spectrum for measurement.

An intermediate carrier frequency of approximately 20 mc is used so the separation between the carrier and sidebands is a larger percentage of the carrier frequency than it would be using the signal generator carrier frequency. It is necessary to use an intermediate frequency due to the selectivity limitations of receivers.

The signal strength is indicated on a VTVM connected to the receivers second detector output which varies linearly with the signal. The meter does not measure the absolute amplitudes of the carrier and sidebands but is used to measure the relative amplitudes by setting a constant RF level at the receiver input.

There are two ways to measure the sideband to carrier ratio. The first, and probably the faster, shown in Fig. 54, uses step attenuators to determine the amount of attenuation needed to reduce the carrier amplitude down to the sideband amplitude. This gives the ratio E_1/E_c directly in decibels.

The second method uses a reference generator operating at the intermediate frequency, matching its output level, as indicated on the VTVM, to the levels of the carrier and sideband (Fig. 55).

Regardless of which method is used the modulation signal must be held at a constant amplitude over the range of modulation frequencies used.

m	△f (kc)	f_{mod} (kc)	E_1/E_c RATIO	E_1/E_c db
.5	50	100	.258	—11.7
.25	50	200	.125	—18
.1	50	500	.050	—26
.05	50	1000 (1 mc)	.025	—32

TABLE I. Modulation Indices ($m = \frac{\Delta f}{f_{mod}}$)

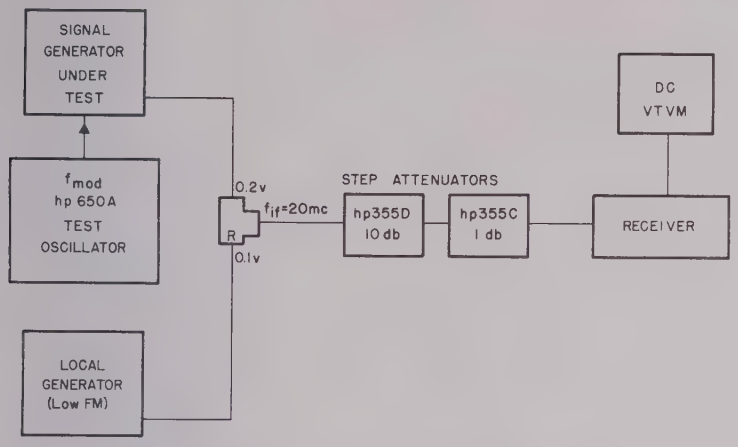


Figure 54. Fidelity Measurement — Step Attenuator Method

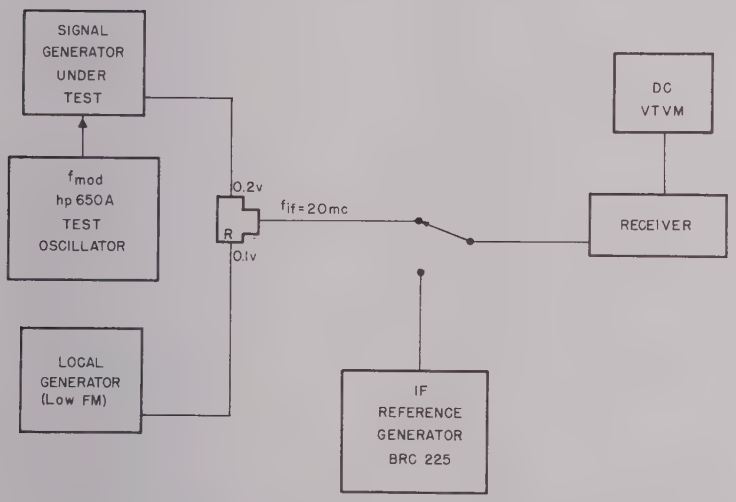


Figure 55. Fidelity Measurement — Reference Generator Method

The amplitude is set for the run by making a Bessel null calibration for 50 kc deviation or whatever deviation is being measured. The second order null for 50 kc deviation occurs at $f/_{mod}$ = 9.058 kc. Using a frequency counter set the frequency of the modulation source. Tune to the carrier with no modulation and then increase the amplitude of the modulation signal until the second order null occurs. The null can be detected on the meter or earphones. The amplitude of modulation frequency which produces the second order null will be used for the rest of the measurements and the results will be based on a known 50 kc deviation reference. It is now known that at f_{mod} of approximately 10 kc "X" volts of modulation signal gives 50 kc deviation. We want to know how close the deviation will be to 50 kc for "X" volts at other modulation frequencies. Now that the amplitude of the modulation signal has been set, the fidelity measurement can be made.

In the set-up (Fig. 54), with the step attenuators set to at least 40 db, the receiver is tuned to the unmodulated IF carrier. Apply the modulation signal, being careful to set its amplitude to the same values obtained for the 50 kc deviation Bessel Null. Adjust the receiver RF gain to give a convenient upscale reading on the VTVM. Tune to the sideband frequency $f_{if} \pm f_{mod}$ and reduce the step attenuation until the VTVM indicates the same receiver RF level as that set for the modulated carrier. The hp 355C step attenuator has 1 db steps, however, the VTVM can be interpolated to at least .25 db.

For a modulation frequency (f_{mod}) of 500 kc and a deviation ($\triangle f$) of 50 kc, the modulation index:

$$m = \frac{\triangle f}{f_{mod}} = 0.10$$

From the graph in Fig. 51 or Table I, the ratio of E_1/E_c for m = 0.10 theoretically equals 0.050 or —26 db.

The 202J FM fidelity specification is ±1 db from 5 cps to 500 kc; therefore, a —25 to —27 db ratio for E_1/E_c at f_{mod} = 500 kc and $\triangle f$ = 50 kc would be within specifications.

If, for example, the ratio E_1/E_c measured —26.5 db at this modulation index, the generator or transmitter FM fidelity would be .5 db below the theoretically ideal unit.

Fig. 52 is nearly linear at the low values of "m" and E_1/E_c. Therefore, if E_1/E_c is .5 db (6%) low, "m" will also be 6% low. The actual modulation index is 0.094 compared to the theoretical value of 0.1. This means that "X" volts of modulation, which gave 50 kc deviation at 10kc, does not give 50 kc deviation at f_{mod} = 500 kc, but actually gives a deviation of:

$\triangle f = m\ f_{mod} = .094 \times 500$ kc = 47 kc.

The second method (Fig. 55), using the reference generator, uses the same intermediate frequency and the modulation signal amplitude as before, as determined by a 50 kc deviation Bessel Null. The receiver is tuned to the unmodulated IF carrier from the mixer and is then switched to the reference generator tuned to the same IF. The reference generator attenuation output is set to 2 Kμv, the modulated carrier (E_c) reference level. Adjust the receiver gain for a convenient upscale reading. Switch the receiver back to the beating generators, apply the modulation signal to the test generator and adjust the local generator output so the VTVM indicates the same level as it did for the 2 Kμv from the reference generator. The carrier amplitude of the modulated IF is now 2 K μv. Make sure it is the carrier by momentarily removing the modulation signal. The carrier will not disappear when the modulation is removed. With the modulation signal back on, tune the receiver to the upper or lower sideband. Change the VTVM range and/or adjust the receiver gain to get an upscale reading for the sideband. Switch to the

reference generator; adjust the frequency to the sideband frequency of $f_{if} \pm f_{mod}$, and adjust its attenuator to give the same reading as the sideband on the VTVM.

The reference generator attenuator reading over the 2 K μv carrier reference equals E_1/E_c.

As an example, for $f_{mod} = 200$ kc and $\triangle f = 50$ kc, m = 0.25. Referring to the graph in Fig. 52 or Table I, we see that m = 0.25 results in a sideband ratio, E_1/E_c, of 0.125 or —18 db. Therefore, with a carrier level of 2 K μv, the first-order sideband amplitude should be 2 K μv x .125 ± 250μv. A specification of ± 1 db at $f_{mod} = 200$ kc means the sideband will be within ± 12% of its ideal values or 220 to 280 μv with m = .25 and 2 K μv carrier. Again, using the linearity of Fig. 52, suppose the ratio of E_1/E_c measured 0.120 (4% low) instead of 0.125 at $f_{mod} = 200$ kc. In this case "m" would also be 4% low. Therefore, instead of 50 kc deviation at $f_{mod} = 200$ kc for "X" volts modulation, as was the case at $f_{mod} = 10$ kc, there will be 4% less deviation or 48 kc.

To make sure that the IF signal is properly limited, check both the upper and lower sidebands to see if AM is distorting the spectrum. If AM is present, it can be minimized by adjusting the levels of the two signals.

SECTION VII

REPLACEMENT PARTS

Tables of replaceable electrical and mechanical parts for the 202J are included in this section. Locations of these parts are given in Fig. 56 through 65 inclusive. When ordering replacement parts, specify the BRC part number and the description given in the replacement parts tables. See Section VI — Maintenance, for detailed disassembly and assembly procedures and for adjustment and/or calibration procedures required after component replacement.

LIST OF MANUFACTURERS

Abbrev.	Manufacturer's Name
AB	Allen-Bradley Company
AER	Aerovox Corporation
AH	Arrow-Hart & Hegeman Electric Company
BC	Bendix Corporation
BI	Beckman Instrument, Inc., Helipot Division
C-D	Cornell-Dublier Electric Corporation
CEC	Corning Electronic Components, Corning Glass Works
CMC	Clorostat Mfg Co., Inc.
CRL	Centralab, Div. of Globe-Union, Inc.
CTS	CTS Corporation
DE	Dale Electronics, Sub. Hathaway Instruments
DEC	Dage Electric Co., Inc.
EMC	Electro Motive Mfg. Company
ERC	Erie Resistor Corporation
FTC	Freed Transformer Company
GA	Good-All Electric Mfg. Company
GE	General Electric Company
GI	Grayhill, Incorporated
HBJ	Howard B. Jones Company
HEC	Hoffman Electronics Corp.
H-P	Hewlett-Packard Company
IRC	International Resistance Company
JED	Jeffers Electronics Div., Speer Carbon Co.
LTF	Littlefuse, Incorporated
MSC	Miller, Sanford Co.
PRM	P. R. Mallory & Company
RCA	Radio Corporation of America
SECO	Sangamo Electric Co.
SEP	Sylvania Electric Products, Semiconductor Div.
SI	Switchcraft, Inc.
SPR	Sprague Electric Co.
TEC	Transitron Electronics Corporation
TI	Texas Instruments, Incorporated
TIC	Technology Instrument Corporation
TMC	Tower Mfg. Corporation
W-L	Ward Leonard Electric Company

TABLE OF REPLACEABLE ELECTRICAL PARTS

CIRCUIT SYMBOL	VALUE	DESCRIPTION	BRC PART NO.	MFG.	MFG'S. TYPE NO.
		RF UNIT			
AT100		Attenuator Assembly, Variable	307798		
C100	10pf	Capacitor: Fixed: ±10%, 500 VDCW	82052	CEC	CY10C-100
C101		Capacitor Assembly, Variable	20116		
C102	20pf	Capacitor: Fixed, Glass, ±5%, 500 VDCW	82054	CEC	CY10C-200
C103	15pf	Capacitor: Fixed, Feedthru, Ceramic, ±10%, 500 VDCW	82051	AB	FA5C
C104	47pf	Capacitor: Fixed, ±5%, 500 VDCW	82157	CEC	CY10C470
C105	75pf	Capacitor: Fixed, Silver Mica, ±10%, 500 VDCW	82159	SECO	DR1475
C106	220pf	Capacitor: Fixed, Ceramic, ±5%, 500 VDCW	82222	ERC	GP2 K
C107	15pf	Capacitor: Fixed, ±5%, 500 VDCW	82063	CEC	CY10C150J
C108	0.5-3pf	Capacitor: Variable, Glass	84088	CEC	680079
C109		Capacitor Assembly: Variable	20198		
C110	100pf	Capacitor: Fixed, ±5%, 500 VDCW	82155	SECO	DR1310
C111, 112	1000pf	Capacitor: Fixed, Feedthru, Silver Mica, ±10%, 500 VDCW	82307	ERC	370-CB-102K
C113	47pf	Capacitor: Fixed, Silver Mica ±5%, 500 VDCW	82158	SECO	DR1447
C114	22pf	Capacitor: Fixed, Silver Mica ±5%, 500 VDCW	82162	SECO	DR1422
C115		Capacitor Assembly: Variable	20197		
C116	0.5-3pf	Same as C108			
C117	10pf	Same as C100			
C118	15pf	Same as C103			
C120	250pf	Capacitor: Fixed, Feedthru, Silver Mica, ±10%, 500 VDCW	82232	ERC	370-CB-251K
C121	1pf	Capacitor: Fixed, Silver Mica, ±1/2 pf, 500 VDCW	82062	C-D	15-5V1
C122	0.5-3pf	Same as C108			
C123		Capacitor Assembly: Variable	20199		
C124	1μf	Capacitor: Fixed, Mylar Film, ±20%, 200 VDCW	83142	GA	620M
C126	220pf	Capacitor: Fixed, Feedthru, Ceramic, ±20%, 500 VDCW	82204	AB	FA5C
C127-129	15pf	Same as C103			
C130-132	270pf	Capacitor: Fixed, Feedthru, Ceramic, ±10%, 500 VDCW	82224	AB	FA5C
C133-135	15pf	Same as C103			
C136-138	10 pf	Capacitor: Fixed, Feedthru, ±10%, 500 VDCW	82064	AB	FA5C
C139-141	270pf	Same as C130			
C142	47pf	Same as C113			
C143	1000pf	Capacitor: Fixed, Standoff, Ceramic, GMV Tol, 500 VDCW	82337	AB	SS5A 102W
C144	47pf	Same as C113			
C145	1000pf	Same as C111			

CIRCUIT SYMBOL	VALUE	DESCRIPTION	BRC PART NO.	MFG.	MFG'S. TYPE NO.
C146, 147	1000pf	Capacitor: Fixed, Ceramic Disc, GMV Tol., 600 VDCW	82306	CRL	BB60-102-NZ5Z
C148	100pf	Capacitor: Fixed, ±10%, 500 VDCW	82125	EMC	
C149	1pf	Same as C121			
C150		Special—P/O AT100—not a replaceable part			
CR100		Diode, Zener: 43-47V	98028	MOT	IN3695B or MZ623-26B
CR101		Diode	91093	TEC	S-1029
J100		Connector, Receptacle: 6 prong	301754	HBJ	S-306-AB
J101		Connector, BNC: UG-909/U	307816	DEC	2230-1
J102		Connector, BNC	89138	DEC	1-310-1
L101	5.5μh	Choke Assembly, RF: Includes Resistor R127	85584		
L102	5.5μh	Choke Assembly, RF: Includes Resistor R128	85584		
L103	15μh	Choke Assembly, RF: Includes Resistor R126	85572		
L104		1st Doubler Coil Assembly	305945		
L105	5.5μh	Choke Assembly, RF: Includes Resistor R129	85584		
L106		Output Coil Assembly	85604		
L107		Loop, Attenuator	307942		
L108		Choke Assembly, RF: Includes R115	85596		
L109-114	50μh	Choke, Filter	85592		
L115	25mh	Choke, Filter	85614	MSC	6308
L116		Same as L109			
L117, 118	10μh	Choke, Filter	85575		
L119	3.3μh	Choke, Filter (Replaces R124)	85458	JED	10102-20
P100		Connector, Plug: 6 prong	112701	HBJ	P-306-CCT-63A-AB
P102		Connector, BNC	89137	DEC	1-317-1
R100	300Ω	Resistor: Fixed, ±5%, 1/8W	80780	TIC	S-18
R101	1.8KΩ	Resistor: Fixed, ±5%, 1/8W	80781	TIC	S-18
R102	1.8KΩ	Resistor: Fixed, ±5%, 1/4W	80271	AB	CB
R103	100Ω	Resistor: Fixed, ±5%, 1/2W	80062	AB	EB
R104	12KΩ	Resistor: Fixed, ±5%, 1/4W	80920	AB	CB
R105	100Ω	Resistor: Fixed, ±5%, 1/4W	80849	AB	CB
R106	300Ω	Resistor: Fixed, ±5%, 1/2W	80779	CEC	C-20
R107	50KΩ	Resistor: Variable, ±10%, 2W	81403	AB	JLU-5031
R108	18KΩ	Resistor: Fixed, ±5%, 2W	80843	AB	HB
R109	8.2KΩ	Resistor: Fixed, ±5%, 2W	80859	CEC	C-42
R110	10KΩ	Resistor: Fixed, ±5%, 1/4W	80833	AB	CB
R111	100KΩ	Resistor: Fixed, ±5%, 1/4W	80592	AB	CB
R112	1KΩ	Resistor: Fixed, ±5%, 1/2W	80148		
R113	12KΩ	Same as R104			
R114	1KΩ	Same as R112			
R115	470Ω	Resistor: Fixed, ±5%, 1/2W, P/O Choke Assembly L108	85596		
R116	22KΩ	Resistor: Fixed, ±5%, 1/2W	80472	AB	EB
R117	50Ω	Resistor: Fixed, Comp., ±1%, 1/8W	80233	DE	DC-1/8
R118	51Ω	Resistor: Fixed, Comp., ±5%, 1/2W	80088	AB	EB
R119	2.7KΩ	Resistor: Fixed, ±5%, 1/2W	80765	AB	EB
R120	10 MegΩ	Resistor: Fixed, ±10%, 1/2W	80682	AB	EB
R121	100Ω	Resistor: Fixed, ±5%, 1/2W	80062	AB	EB
R122	22Ω	Resistor: Fixed, ±5%, 1/2W	80037	AB	EB

CIRCUIT SYMBOL	VALUE	DESCRIPTION	BRC PART NO.	MFG.	MFG'S. TYPE NO.
R123	100Ω	Same as R121			
R124		Replaced by L119			
R125	3.3KΩ	Resistor: Fixed, ±5%, 1/2W	80253	AB	EB
R126	15KΩ	Resistor: Fixed, ±5%, 1/2W, P/O L103	85572		
R127-129	10KΩ	Resistor: Fixed, ±5%, 1/2W, P/O L101, L102, and L105	88584		
T100		Oscillator Coil Assembly	305946		
V100		Tube, Electron	6688		
V101		Tube, Electron	6AF4		
V102, 103		Same as V100			
		POWER SUPPLY			
C200	1500μf	Capacitor: Fixed, Electrolytic, 50 VDCW	83171	PRM	WF-068
C201A, B	16-16μf	Capacitor: Fixed, Electrolytic, 450 VDCW, W/Mtg. Clamp	83170	C-D	BBRD-16D45
C202, 203	8μf	Capacitor: Fixed, Electrolytic, 450 VDCW, W/band	83028	AER	PRS-450VDC
C204	.05μf	Capacitor: Fixed, Ceramic Disc, +80%—20%, 50 VDCW	83180	C-D	H-05S5
CR200-203		Rectifier, Silicon: 500 PIV, 1/2A	98006	RCA	INI764
CR204, 205		Rectifier, Silicon: 50 PIV, 3A, W/Mtg. Kit	98019	TEC	INI581
CR206, 207		Rectifier, Silicon: 400 PIV, 1/2A (CR207 not used in all instruments—See CR209.)	91100	RCA	INI763
CR208		Diode, Zener: 7.5-8.2V, 6W	98020	H-P	G-31H-8L
		Diode, Zener: 7.5-8.2V, 6W	98030	H-P	G-31G-8L
CR209		Diode, Zener: 82V, 10W, 10%	98012	MOT	10M82Z10
		Diode, Zener: 91V ±10%, 10W (Used as CR209 with CR207 in same instruments)	98027	MOT	IN3004RA
CR210		Diode, Zener: 6.8-7.5V, 90MW	98000	H-P	G-31A-7H
		Diode, Zener: 5-7V, 150 MW	98026	HEC	RT6
CR211		Same as CR206			
CR212, 213		Diode, Zener: 6.8-7.5V, 1.2W	98002	H-P	G-31G-7H
DS200		Lamp, Incandescent: 6.3V, 0.15A, 2 pin base	90910	GE	#12
F200		Fuse: 3A, 115V, 3AG2	93252	LTF	312.003
		Fuse: 1.5A, 230V, 3AG	93250	LTF	31201.5
# F201		Fuse: 3A, 115V, 3AG2	93252	LTF	312.003
		Fuse: 3A, 115V, 3AG, SLO BLO	95032	LTF	313.003
L200	4h	Choke, Filter	85452	FTC	34764
L201	5h	Choke, Filter	85412	FTC	24913
P200		Connector, Receptacle: Male, 3 pin	308087	TMC	H-1061-IG
Q200		Transistor	98502	BC	2N1136
Q201		Transistor	98505	MOT	2N1533
Q202-204		Transistor	98504	TI	2N1379
R200	400Ω	Resistor: Fixed, WW, ±10%, 10W	80806	W-L	10F
R201	600Ω	Resistor: Variable, WW, ±10%, 10W	81134	W-L	10A
R203	13KΩ	Resistor: Fixed, ±5%, 2W	80916	AB	HB
R204	12KΩ	Resistor: Fixed, ±5%, 2W	80868	AB	HB
R205	30Ω	Resistor: Fixed, ±5%, 2W	80815	CEC	C-42
R206	15KΩ	Resistor: Fixed, ±3%, 3W	80813	DE	RS-2B
† R207	3KΩ	Resistor: Variable, ±10%, 1/2W	81136	IRC	RQL11-112
	400Ω	Resistor: Variable, ±5%, 2W	81142	CMC	43C2-400

Use fuse indicated on rear panel of instrument.

† See Fig. 66 Schematic 202J Revisions.

	SYMBOL CIRCUIT	VALUE	DESCRIPTION	BRC PART NO.	MFG.	MFG'S. TYPE NO.
†	R208	14KΩ	Resistor: Fixed, ±3%, 3W	80811	DE	RS-2B
		15KΩ	Resistor: Fixed, ±3%, 3W	80813	DE	RS-2B
†	R209	750Ω	Resistor: Fixed, WW, ±3%, 3W	80869	DE	RS-2B
		470Ω	Resistor: Fixed, WW, ±3%, 3W	134951	DE	RS-2B
	R210, 211	470Ω	Resistor: Fixed, Comp., ±5%, 1/2W	80168	AB	EB
	R212	75KΩ	Resistor: Fixed, Comp., ±5%, 2W	80510	AB	EB
	R213	15KΩ	Resistor: Fixed, Comp., ±5%, 1/2W	80336	AB	EB
	R214	15KΩ	Same as R206			
	R215, 216	51Ω	Resistor: Fixed, ±5%, 1/2W	80088	AB	EB
	R217	18KΩ	Resistor: Fixed, ±5%, 2W	80843	AB	HB
	S200		Switch, Toggle	88059	AH	81027CE
	S201		Switch, Snap Slide	88003	H-P	3101-0033
	T200		Transformer, Power	85087		
	W200		Power Cord Assembly	308086		
			AGC AMPLIFIER			
	C300	10μf	Capacitor: Fixed, Electrolytic, 25 VDCW	83181	AER	PTT79
	C301	10μf	Capacitor: Fixed, 6 VDCW	83131	AER	PTT23
†	C302	25μf	Capacitor: Fixed, 50 VDCW	83166	AER	PTT95
†	C303	25μf	Capacitor: Fixed, 50 VDCW	83166	AGR	PTT95
†	CR300		Diode, Zener: 6.8-7.5V, 90MW	98000	H-P	G-31A-7H
†	CR301, 302		Diode, Zener: 11-12V, 90MW	98017	H-P	G-31A-12L
†	CR303		Diode, Zener. 6.8-7.5V, 1.2W	98002	H-P	G-31G-7H
†	CR304		Diode, Zener: 24V, ±10%, 3/4W	98029	MOT	IN3688A
	M300		Meter, RF Monitor	92050-1		
	R300	50KΩ	Resistor: Variable, ±30%, 0.2W	81516	CTS	Type 70
	R301	22KΩ	Resistor: Fixed, ±5%, 1/2W	80472	AB	EB
	R302	1KΩ	Resistor: Variable, ±10%, 2W	81225	AB	Type J
†	R303	150KΩ	Resistor: Fixed, ±5%, 1/2W	80527	AB	EB
		220KΩ	Resistor: Fixed, ±5%, 1/2W	80555	AB	EB
†	R304	1KΩ	Resistor: Fixed, ±5%, 1/2W	80148	AB	EB
		3.3KΩ	Resistor: Fixed, ±5%, 1/2W	80253	AB	EB
	R306	470KΩ	Resistor: Fixed, ±5%, 1/2W	80640	AB	EB
†	R307	18KΩ	Resistor: Fixed, ±5%, 1W	80784	CEC	C-32
†	R308	500KΩ	Resistor: Variable, ±30%, 0.2W	81621	CTS	Type 70
		200KΩ	Resistor: Variable, ±30%, 0.2W	81519	CTS	Type 70
†	R309	68KΩ	Resistor: Fixed, ±5%, 1/2W	80549	AB	EB
†	R310	33KΩ	Resistor: Fixed, ±5%, 1/2W	80461	AB	EB
		24KΩ	Resistor: Fixed, ±5%, 1W	80464	AB	GB
†	R311, R314	220KΩ	Resistor: Fixed, ±5%, 1/2W	80555	AB	EB
†	R312	220Ω	Resistor: Fixed, ±5%, 1/2W	80188	AB	EB
		6.8KΩ	Resistor: Fixed, ±5%, 1/2W	80387	AB	EB
	V300A, B		Tube, Electron: 6AW8A			
			FM CATHODE FOLLOWER			
	C400	.2μf	Capacitor: Fixed, Mylar, 400V	83173	GA	620M
	C401	.33μf	Capacitor: Fixed, ±10%, 100 VDCW	83178	GA	633F

† See Fig. 66, Schematic 202J Revisions.

SYMBOL CIRCUIT	VALUE	DESCRIPTION	BRC PART NO.	MFG.	MFG'S. TYPE NO.
C402	.47μf	Capacitor: Fixed, ±10%, 100 VDCW	83179	GA	633F
C403	.001μf	Capacitor: Fixed, Ceramic, ±20%, 1000 VDCW	82351	SPR	5GA-010
CR400		Diode, Zener: 47V, 6W	98023	MOT	1N2995-B
J400, 401		Binding Post: Red	304312	GI	29-IR
J402		Binding Post: Black	304311	GI	29-IB
J403		Jack, Phone: Open Circuit	89038	SI	#11
R400	100Ω	Resistor: Fixed, ±5%, 1/2W	80062	AB	EB
R401	470KΩ	Same as R306			
R402	3.9KΩ	Resistor: Fixed, Metal Film, ±5%, 2W	80912	CEC	C-42
R403	3.3KΩ	Resistor: Fixed, ±5%, 2W	80914	CEC	C-42
R404	100KΩ	Resistor: Fixed, ±5%, 1/2W	80517	AB	EB
R405	180Ω	Resistor: Fixed, ±5%, 1/2W	80222	AB	EB
R406	4.7KΩ	Resistor: Fixed, ±5%, 1W	80305	AB	GB
R407	470KΩ	Same as R306			
R408	332KΩ	Resistor: Fixed, Carbon Film, ±1%, 1/2W	80785	TI	CD1/2PR
R410	1KΩ	Resistor: Variable, ±5%, 2W	81132	BI	SG-832
R411	1MEGΩ	Resistor: Fixed, ±1%, 1/2W, Carbon Film	80799	TI	CD1/2PR
R412	2MEGΩ	Resistor: Fixed, ±1%, 1/2W	80972	TI	CD1/2PR
R413	21KΩ	Resistor: Fixed, ±1%, 1/2W	80822	TI	CD1/2PR
R414	150KΩ	Same as R303			
R415	4.7KΩ	Resistor: Fixed, ±5%, 1/2W	80915	CEC	C-20
R416	2KΩ	Resistor: Variable, ±30%, 0.2W	81214	CTS	Type 70
R417	100Ω	Same as R400			
R419	500KΩ	Resistor: Variable, Carbon Comp, ±10%, 0.2W	81621	CTS	Type 70
V400A, B		Tube, Electron: 6BK7B			
		AUDIO OSCILLATOR AND AM CATHODE FOLLOWER			
C500	.01μf	Capacitor: Fixed, Silver Mica, ±1%, 500 VDCW	82454	C-D	1DR5S1
C501	.001μf	Capacitor: Fixed, Silver Mica, ±1%, 500 VDCW	82340	C-D	5R501
C502	.01μf	Same as C500			
C503	985pf	Capacitor: Fixed, Silver Mica, ±1%, 500 VDCW	82341	C-D	5R5T985R
C504	7-45pf	Capacitor: Variable	84039	ERC	N500TS2B
C505, 506	390pf	Capacitor: Fixed, Silver Mica, ±1%, 500 VDCW	82227	C-D	22R5T39
C507, 508	270pf	Capacitor: Fixed, Silver Mica, ±1%, 500 VDCW	82246	C-D	22R5T27
C509	7-45pf	Same as C504			
C510	.1μf	Capacitor: Fixed, Mylar Film ± 20%, 400 VDCW	82456	GA	620M
C511A, B	20-20μf	Capacitor: Fixed, Electrolytic, 450 VDCW	83051	C-D	UP2245
C512	8μf	Same as C202			
C513	.5μf	Capacitor: Fixed, Mylar Film, ±10%, 200 VDCW	83161	GA	620M
C514	40μf	Capacitor: Fixed, Electrolytic, 350 VDCW, W/Mtg. Clamp	83164	C-D	BR4035
C516	60μf	Capacitor: Fixed, Electrolytic, 300 VDCW, W/Insul. Cover	83100	SPR	TVL-1570

CIRCUIT SYMBOL	VALUE	DESCRIPTION	BRC PART NO.	MFG.	MFG'S. TYPE NO.
CR500		Diode, Crystal; 60 PIV, 50MA	91081	SEP	IN34A
I500		See RT500			
J500		Jack: Closed Circuit	89039	SI	12A
R500, 501	332KΩ	Resistor: Fixed, Carbon Film, ±1%, 1/2W	80785	TI	CD1/2PR
R502, 503	40.2KΩ	Resistor: Fixed, Carbon Film, ±1%, 1/2W	80786	TI	CD1/2PR
R504, 505	9.31KΩ	Resistor: Fixed, Carbon Film, ±1%, 1/2W	80787	TI	CD1/2PR
R506, 507	14.7KΩ	Resistor: Fixed, Carbon Film, ±1%, 1/2W	80788	TI	CD1/2PR
R508, 509	5.11KΩ	Resistor: Fixed, Carbon Film, ±1%, 1/2W	80789	TI	CD1/2PR
R510	10KΩ	Resistor: Variable, ±10%, 2W	81314	AB	JLU-1031
R511	150KΩ	Resistor: Fixed, ±5%, 1/2W	80527	AB	EB
R512	470KΩ	Same as R306			
R513	220KΩ	Resistor: Fixed, ±5%, 1/2W	80555	AB	EB
R514	6.8KΩ	Resistor: Fixed, Metal Film, ±10%, 4W	80790	CEC	LPI-4
R515	510Ω	Resistor: Fixed, ±5%, 1W	80128	AB	GB
R516	6.8KΩ	Resistor: Fixed, ±5%, 1W	80322	AB	GB
R517	100KΩ	Resistor: Fixed, ±5%, 1/2W	80517	AB	EB
R518	470Ω	Resistor: Fixed, ±5%, 1/2W	80168	AB	EB
R519	7.5KΩ	Resistor: Fixed, Metal Film, ±5%, 2W	80357	CEC	C-42
R520	10KΩ	Resistor: Variable, ±10%, 2W	81340	AB	Type J
R521	820Ω	Resistor: Fixed, ±5%, 1/2W	80171	AB	EB
R522	100Ω	Same as R400			
R523	1 MegΩ	Resistor: Fixed, ±5%, 1/2W	80621	AB	EB
RT500		Lamp, Incandescent: 120V, 3W	90907	GE	3S6/5
S500		Switch, Rotary	88058		
V500		Tube, Electron: 6AU6A			
V501		Tube, Electron: 6AQ5A			
V502		Tube, Electron: 12AU7A			

MODULATION METER CIRCUIT

C600	.5μf	Same as C513			
C601	100μf	Capacitor: Fixed, Electrolytic, 6 VDCW	83133	AER	PTT30
C602, 603	.1μf	Same as C510			
C604, 605	1μf	Capacitor: Fixed, Mylar, ±20%, 100 VDCW	83125	GA	663A
C606	5pf	Capacitor: Fixed, ±5%, 500 VDCW	82060	C-D	15-5V5
C607	.001μf	Same as C403			
C608	.1μf	Same as C510			
CR600		Same as CR206			
CR601, 602		Diode, Silicon: 120 PIV	98022	TI	IN660
CR603		Same as CR206			
M600		Meter, Modulation	92051-1		
R600	120KΩ	Resistor: Fixed, ±5%, 1/2W	80550	AB	EB
R601	390Ω	Resistor: Fixed, ±5%, 1/2W	80182	AB	EB
R602	15KΩ	Resistor: Fixed, ±5%, 1/2W	80336	AB	EB
R603	1.8KΩ	Resistor: Fixed, ±5%, 1/2W	80234	AB	EB
R604	390KΩ	Resistor: Fixed, ±5%, 1/2W	80611	AB	EB
R605	390Ω	Same as R601			
R606	15KΩ	Same as R602			
R607	1.8KΩ	Same as R603			
R608	390KΩ	Same as R604			

CIRCUIT SYMBOL	VALUE	DESCRIPTION	BRC PART NO.	MFG.	MFG'S. TYPE NO.
R609	100Ω	Same as R312			
R610	82Ω	Resistor: Fixed, ±5%, 1/2W	80059	AB	EB
R611	4.02KΩ	Resistor: Fixed, Carbon Film, ±1%, 2W	80861	TJ	CD2R
R612	100KΩ	Resistor: Variable, ±30%, 0.2W	81517	CTS	Type 70
R613	56KΩ	Resistor: Fixed, Metal Film, ±5%, 1/2W	80804	CEC	C-20
R614	180KΩ	Resistor: Fixed, Metal Film, ±5%, 1W	80851	CEC	C-32
R615-617	100Ω	Same as R400			
V600, 601		Tube, Electron: 6AU6A			
V602		Tube, Electron: 6DJ8			
		SWITCHING			
C700	680pf	Capacitor: Fixed, Mica, ±20%, 500 VDCW	82343	C-D	BYA10T68
C702	.5μf	Capacitor: Fixed, Mylar Film, ±10%, 200 VDCW	83161	GA	620M
R701	27KΩ	Resistor: Fixed, ±5%, 1/2W	80463	AB	EB
R702	5KΩ	Resistor: Variable, ±10%, 2W	81318	AB	Type J
R703	3.16KΩ	Resistor: Fixed, Carbon Film, ±1%, 1/2W (Formerly 4.02KΩ)	131508	TI	CD1/2PR
R704	1KΩ	Resistor: Fixed, Carbon Film, ±1%, 1/2W	80185	TI	CD1/2PR
R705	800Ω	Resistor: Fixed, Carbon Film, ±1%, 1/2W	80793	TI	CD1/2PR
R706, 707	100Ω	Resistor: Fixed, Carbon Film, ±1%, 1/2W	80794	TI	CD1/2PR
R714	24.9Ω	Resistor: Fixed, Carbon Film, ±1%, 1/2W	80805	TI	CD1/2PR
R715	68Ω	Resistor: Fixed, Comp., ±5%, 1/2W	80057	AB	EB
R718	715Ω	Resistor: Fixed, Carbon Film, ±1%, 1/2W	80870	TI	CD1/2PR
R719	309Ω	Resistor: Fixed, Carbon Film, ±1%, 1/2W	80871	TI	CD1/2PR
R720	32.4Ω	Resistor: Fixed, Carbon Film, ±1%, 1/2W (Formerly 31.6Ω)	131507	TI	CD1/2PR
R721	250Ω	Resistor: Variable, ±30%, 0.2W	81424	CTS	Type 70
R726	27KΩ	Same as R701			
S700A-F		Switch, Rotary: INT MOD	307949		
S701A, B		Switch, Rotary: DEV KC	307951		
S702A, B		Switch, Rotary: DPDT	88060		

TABLE OF REPLACEABLE MECHANICAL PARTS

BRC PART NO.	DESCRIPTION	QTY. PER UNIT
20112	Deviation Rotor Assembly	1
20115	Bracket, Main Drive Shaft	1
20241	Rotor Wiper Spring Assembly	4
20248	Can, Shield	1
20272	RF Shielding Braid	1
20276	Stator Mount	3
70097	Collar	1
84048	Plate, Stop	1
84052	Rotor	1
84053	Stator, Variable Capacitor	1
84054	Stator, Variable Capacitor	1
84055	Stator, Variable Capacitor	1
88826	Shield, Electron Tube (V400, V502, V602)	3
89075	Shield, Electron Tube (V101)	1
89088	Shield, Electron Tube (V500, V600, V601)	3
89099	Socket, Electron Tube (V100, V102, V103)	3
89113	Socket, Lamp: RT 500	1
89139	Socket, Electron Tube (V500, V501, V600, V601)	4
89140	Socket, Electron Tube (V300, V400, V502, V602)	4
89142	Lamp Holder Assembly: DS200	1
90064-5	Terminal Strip Assembly	2
90064-7	Terminal Strip Assembly	1
90064-8	Terminal Strip Assembly	2
93155	Bearing, Thrust	1
94231	Gear	1
98800	Transistor Mount — (Q200, Q201) — Used on Instruments Serial Numbered 5928 and below.	2
98002	Clip, Mounting: Q202	1
98803	Clip, Mounting: Double, Q203, Q204	1
98804	Transistor Socket — (Q200, Q201) — Used on Instruments Serial Numbered 5928 and above.	2
211521	Clamp, Dial Lock	1
211576	Washer, Spring	1
300029	Spacer, Shaft	1
300065	Washer, Flat	6
300080	Washer, Spring	4
300081	Ring, Retaining	
300085	Stop Collar Assembly	1
300162	Socket, Electron Tube: V101	1
300331	Terminal, Insulated	19
300856	Terminal, Insulated	4
301684	Shield, Electron Tube: (V300)	1
301944	Gear	1
302324	Gear and Pin Assembly	1
302652-3	Shield, Electron Tube: (V100, V102)	2
302652-5	Shield, Electron Tube: (V501)	1
303179	Ring, Retaining	1

BRC PART NO.	DESCRIPTION	QTY. PER UNIT
303222	Gasket, Shielding	1
303375	Washer, Flat	1
304217	Clamp, Loop: Burndy HP-7N	4
304467	Clamp, Loop: Burndy HP-5N	3
304469	Clamp, Loop: Burndy HP-4N	1
304501	Clamp, Loop: Burndy HP-9N	2
304505	Clamp, Loop: Burndy HP-6N	1
305149	Cable	1
306511	Fuseholder Post	2
306577	Knob	4
306579	Knob	1
306579-1	Knob	1
306588	Knob	2
306616	Knob	4
307671	Stud, Shield Can Retainer	3
307675	Washer, Flat	5
307700	Terminal Board	1
307705	Dial Assembly, Frequency	1
307708	Dial Assembly, Attenuator	1
307777	Bellows, Coupling Shaft	2
307784	Dial Assembly, Vernier	1
307791	Fiducial, Attenuator	1
307793-2	Gear Box Subassembly	1
307806	Fiducial, △F KC and VERNIER	2
307807	Fiducial, Frequency	1
307817	Holder, Shock Mount	4
307818	Snubbing Washer: Flat	8
307819	Snubbing Collar: Rubber	4
307862	Insulator, Transistor: Q201	2
307921	Spacer: Threaded, Hex	4
307922	Spacer: Threaded, Hex	2
307931-2	Rear Plate Assembly	1
307934	Tube & Support Assembly	1
307935	Shaft, Attenuator	1
307937	Washer, Flat	1
307964	R. F. Filter Assembly	1
307977	Block, Mounting	1
307978	Collar, Clamp	1
307982	Bushing, Shaft	1
307990	Dial Assembly, △F KC	1
307995	Collar & Pin Assembly	1
308000	Shaft Assembly, Frequency	1
308132	Side Handle Assembly	2
308136	Strip, Large Filler	1
308137-51	Strip, Trim (Adhesive Backed)	2
308155	Nut, Clip: Tinnerman	8
308534	Terminal Board	1
308539	Bearing, Plate	1
308547	Clamp, Loop: Tinnerman C2980-9-A27 (C124)	1
308589	Terminal Strip	1
308646	Bushing, Dial Lock	1
308648	Cam Shaft Assembly (Includes gear)	1
308649	Gear	1

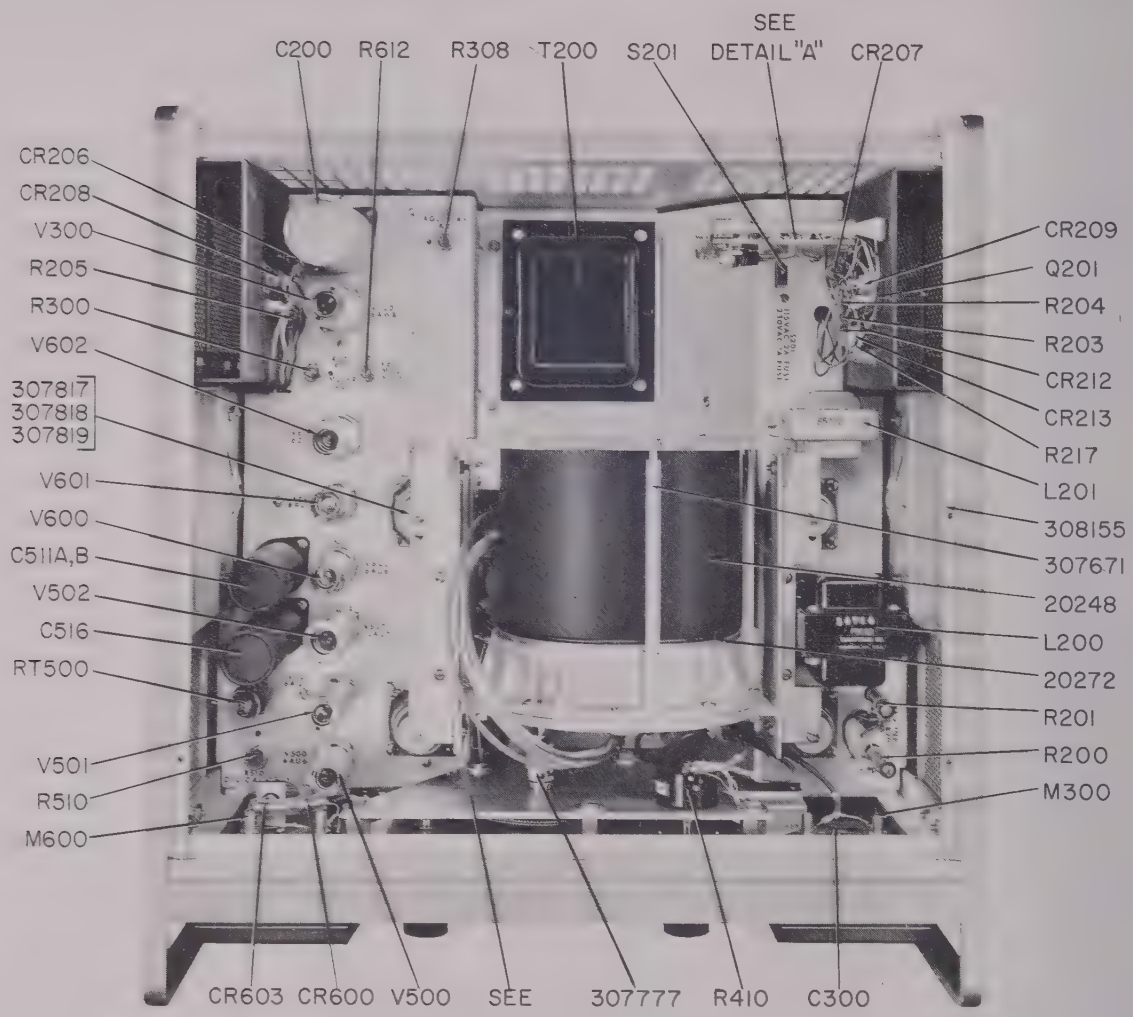
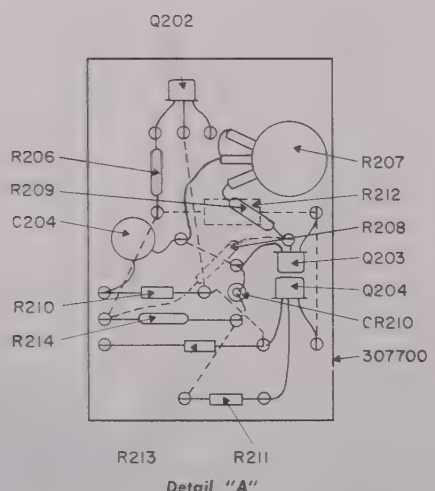
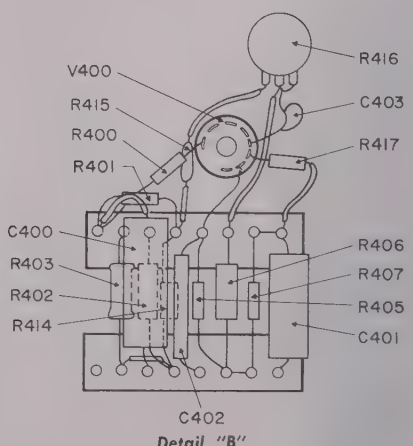


FIG. 65

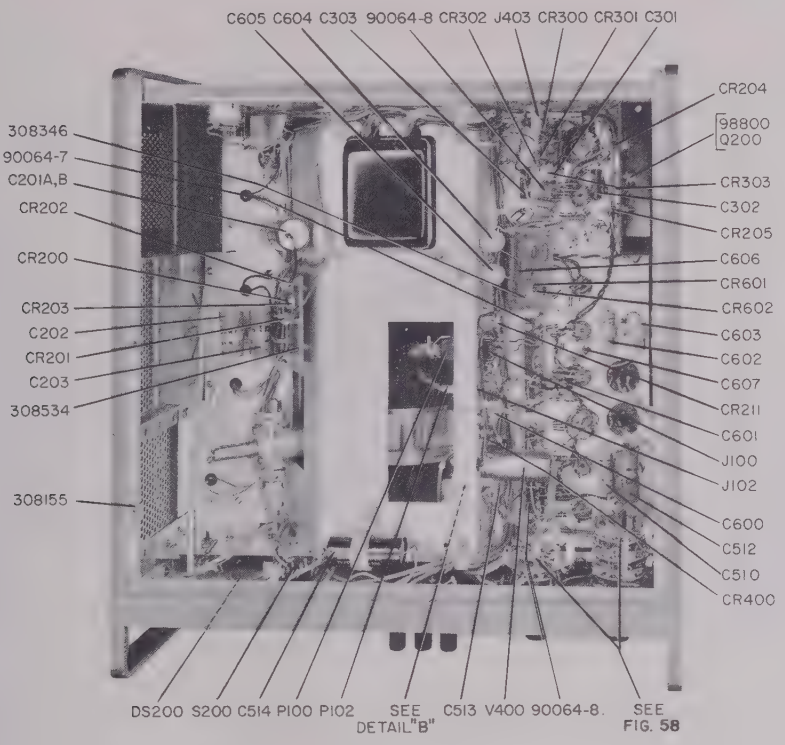
Figure 56. 202J — Top View



Detail "A"



Detail "B"



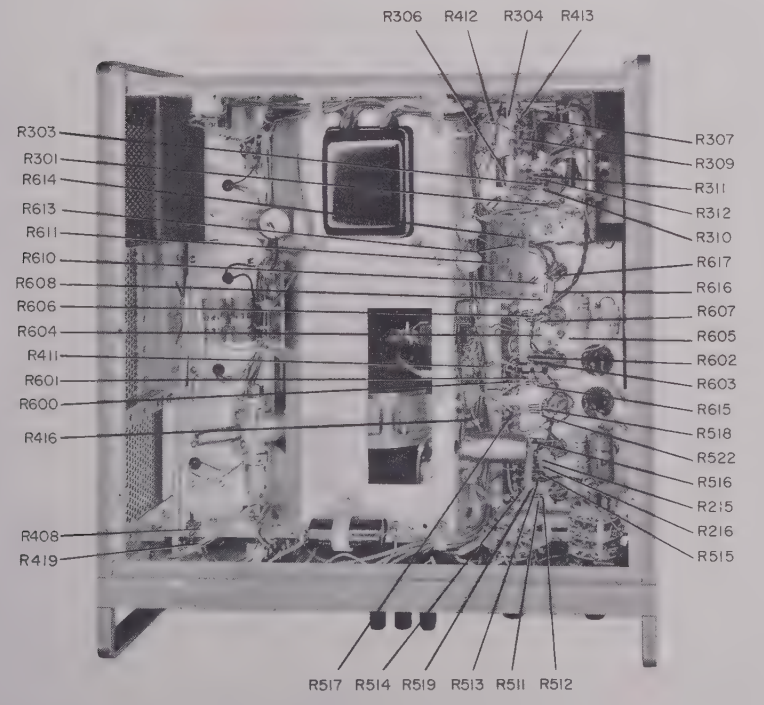


Figure 57. 202J — Bottom View

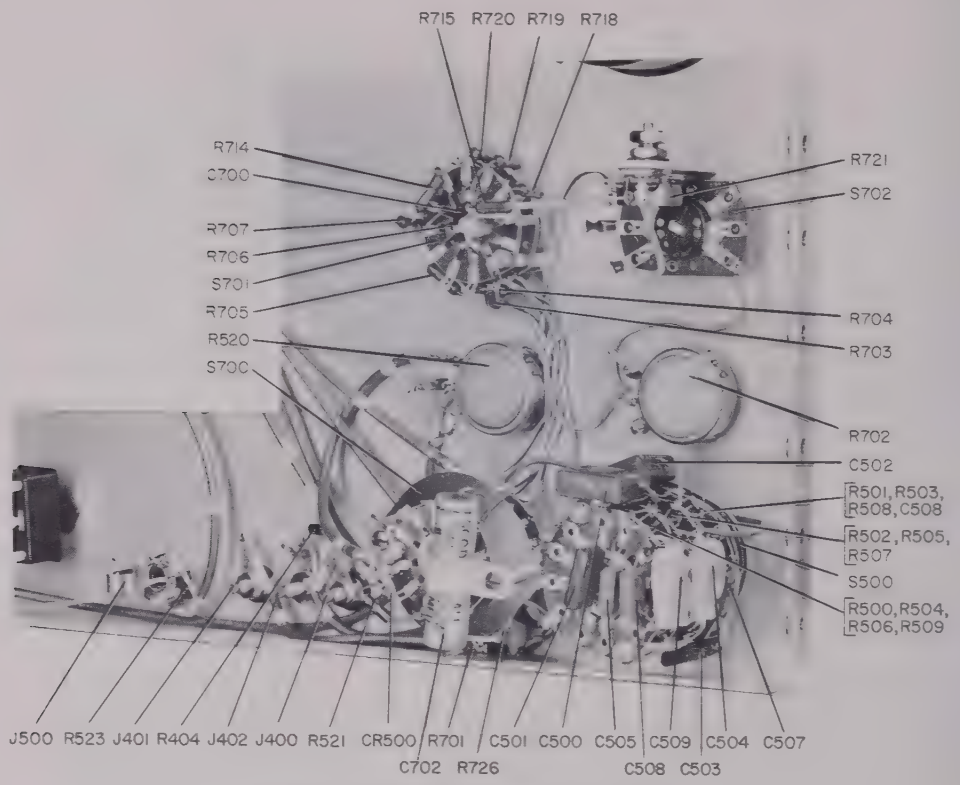


Figure 58. 202J Front Panel — Rear View

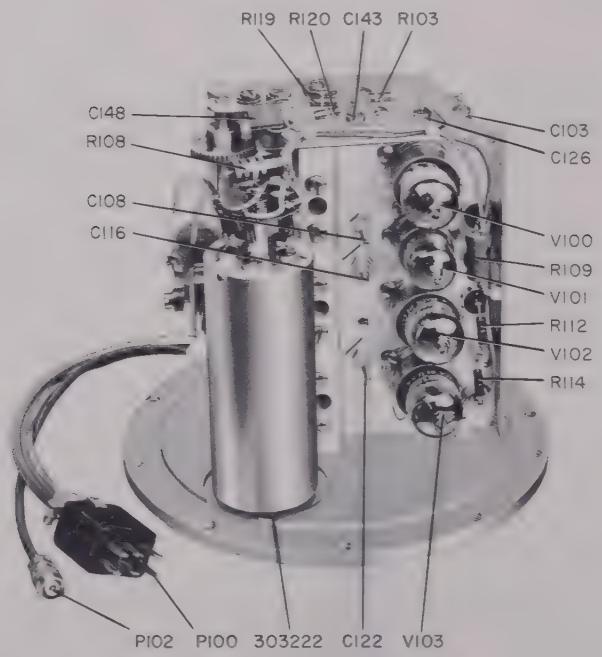


Figure 59. RF Unit — Top View

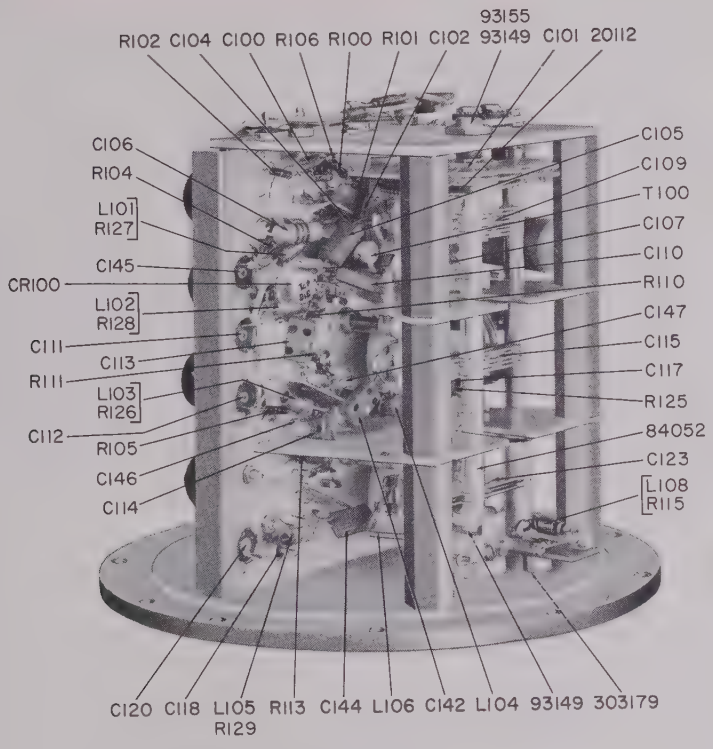


Figure 60. RF Unit — Bottom View

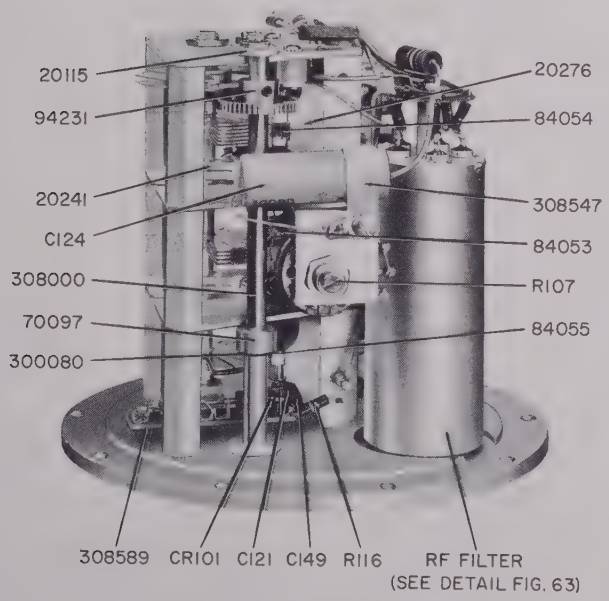


Figure 61. RF Unit — Side View

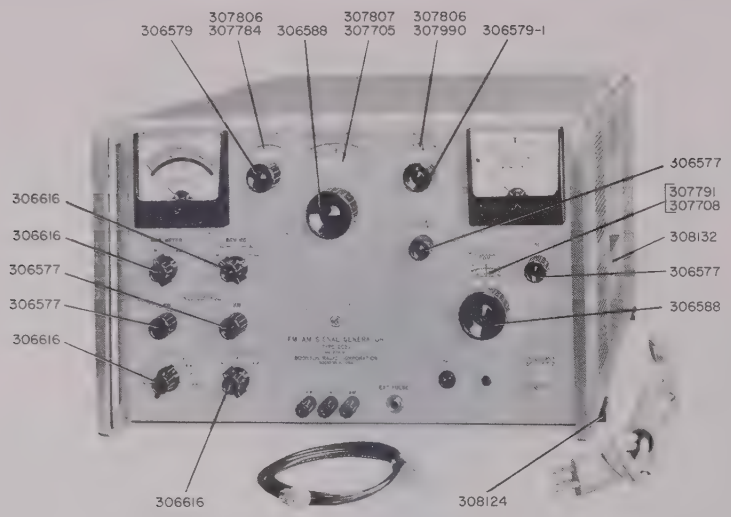


Figure 62. 202J Front Panel Mechanical Parts

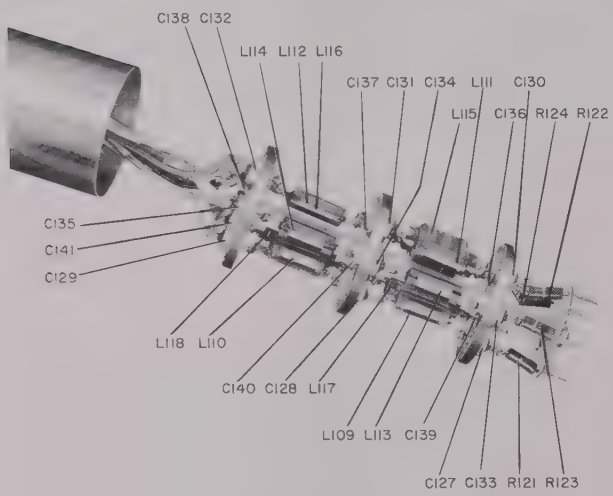


Figure 63. RF Filter

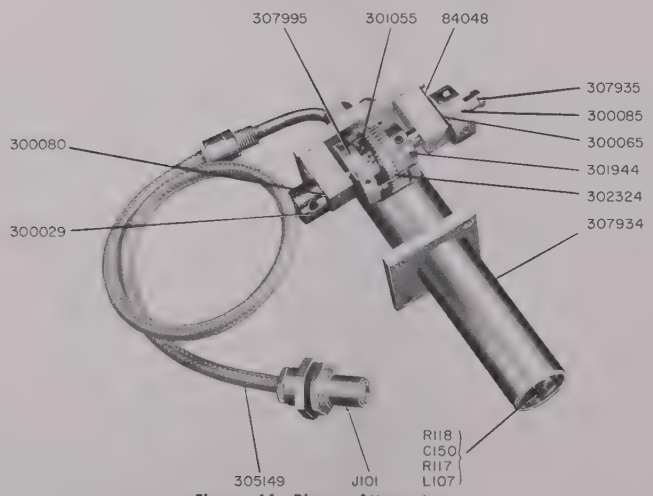


Figure 64. Piston Attenuator

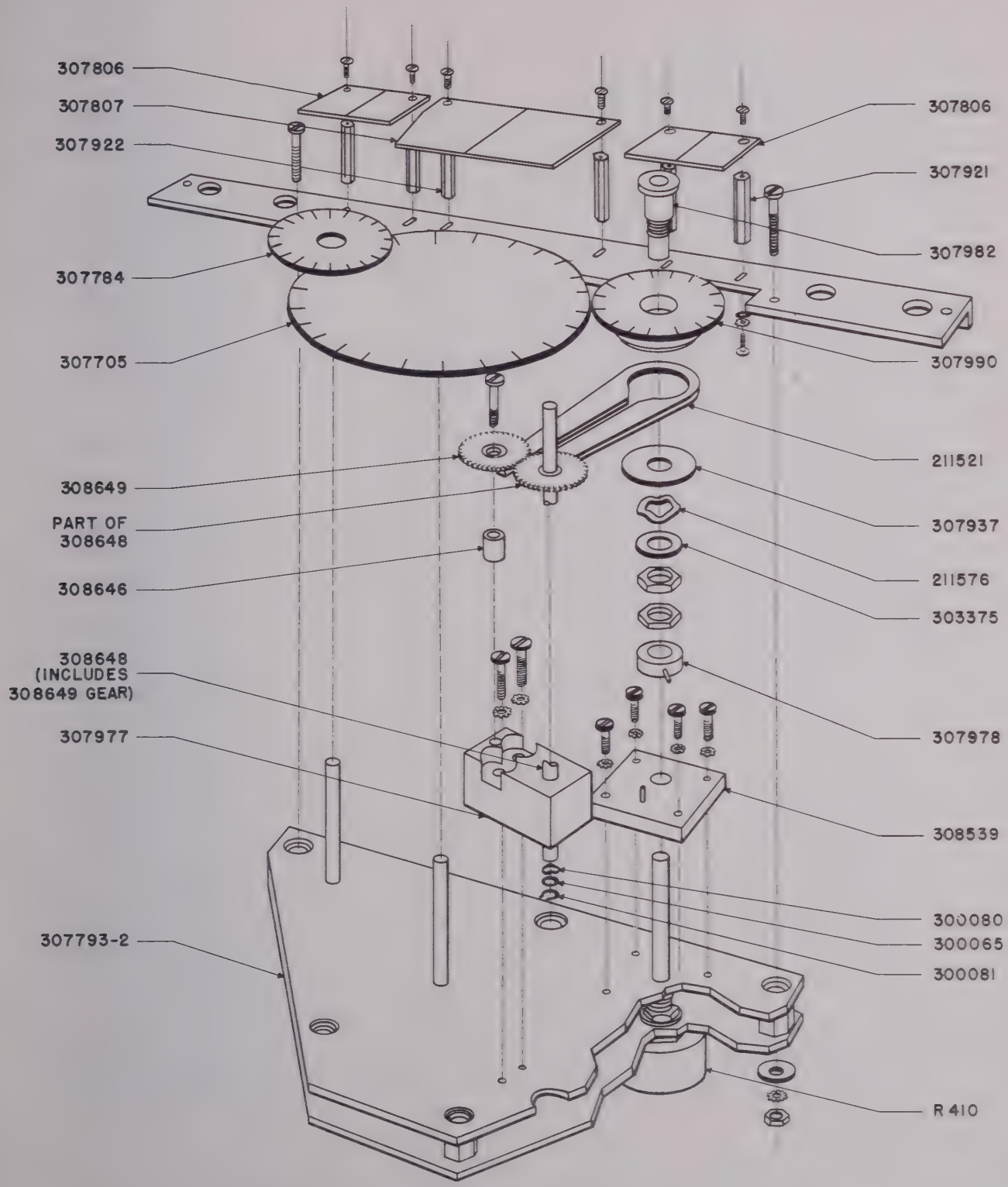
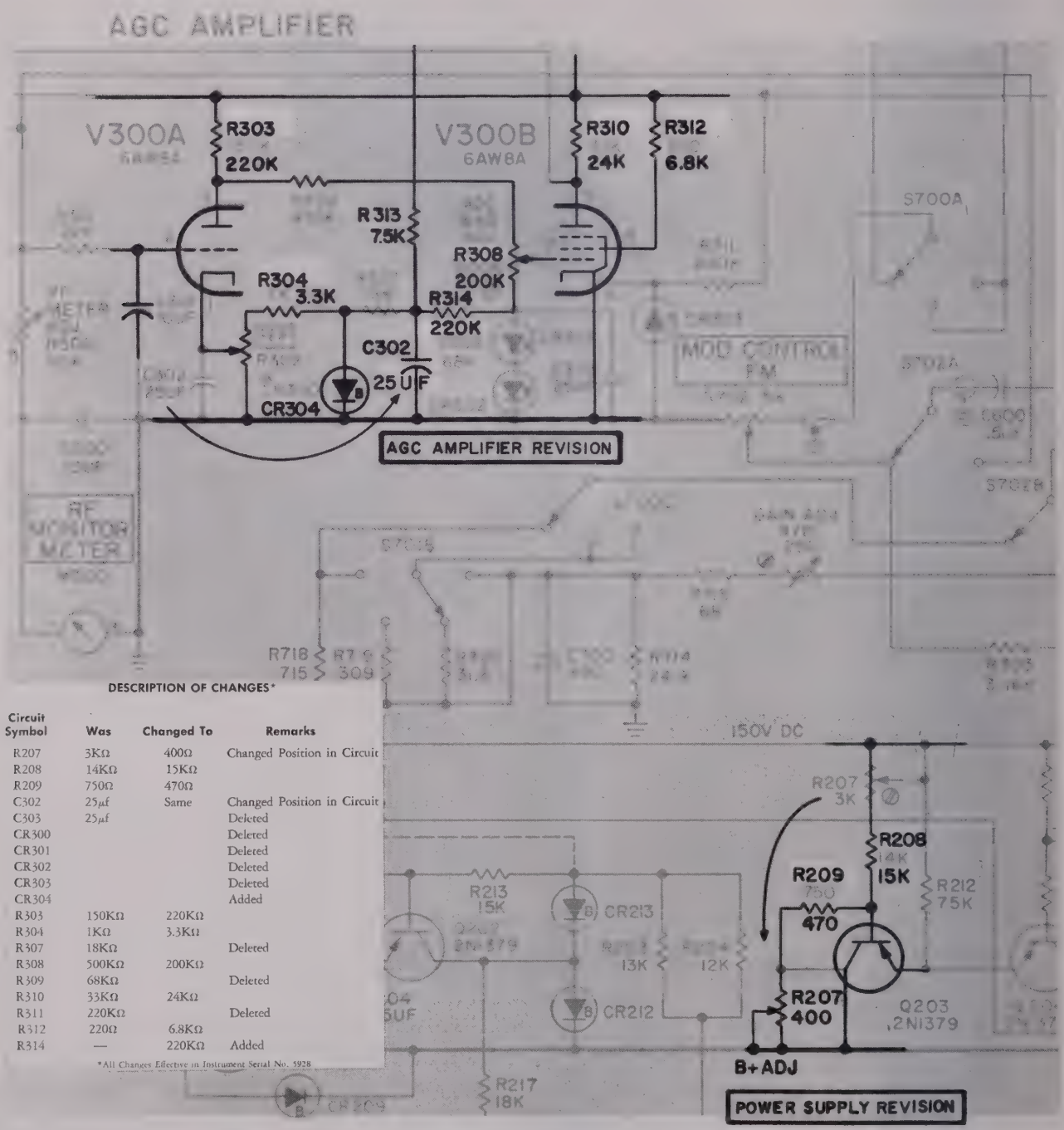


Figure 65. Gear Box Assembly

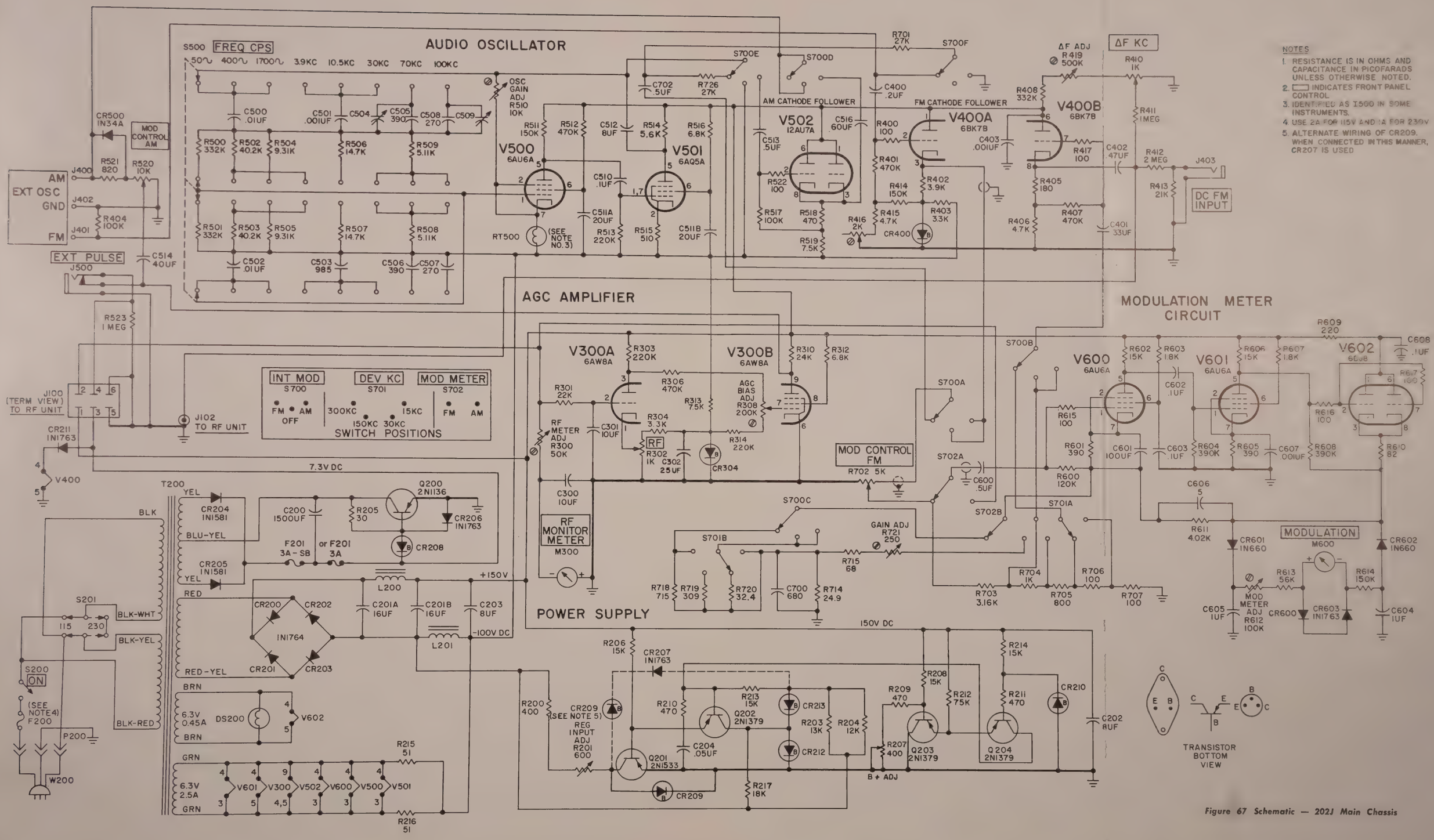


DESCRIPTION OF CHANGES*

Circuit Symbol	Was	Changed To	Remarks
R207	3KΩ	400Ω	Changed Position in Circuit
R208	14KΩ	15KΩ	
R209	750Ω	470Ω	
C302	25μf	Same	Changed Position in Circuit
C303	25μf		Deleted
CR300			Deleted
CR301			Deleted
CR302			Deleted
CR303			Deleted
CR304			Added
R303	150KΩ	220KΩ	
R304	1KΩ	3.3KΩ	
R307	18KΩ		Deleted
R308	500KΩ	200KΩ	
R309	68KΩ		Deleted
R310	33KΩ	24KΩ	
R311	220KΩ		Deleted
R312	220Ω	6.8KΩ	
R314	—	220KΩ	Added

*All Changes Effective on Instrument Serial No. 5928

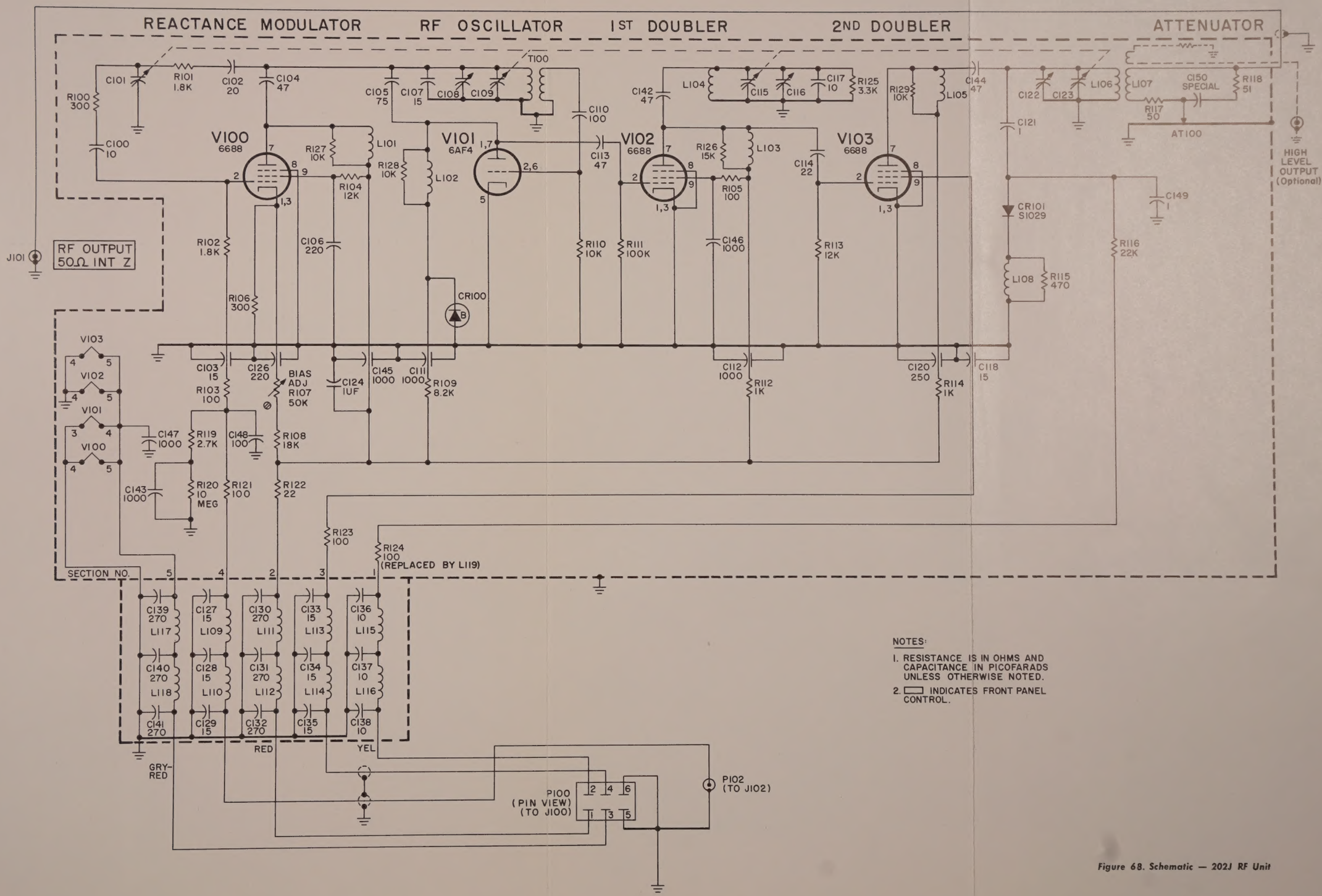
Figure 66. Schematic — 202J Revisions



NOTES

1. RESISTANCE IS IN OHMS AND CAPACITANCE IN PICOFARADS UNLESS OTHERWISE NOTED.
2. ▭ INDICATES FRONT PANEL CONTROL
3. IDENTIFIED AS T500 IN SOME INSTRUMENTS.
4. USE 2A FOR 115V AND 1A FOR 230V
5. ALTERNATE WIRING OF CR209. WHEN CONNECTED IN THIS MANNER, CR207 IS USED

Figure 67 Schematic — 202J Main Chassis



NOTES:

1. RESISTANCE IS IN OHMS AND CAPACITANCE IN PICOFARADS UNLESS OTHERWISE NOTED.
2. ▭ INDICATES FRONT PANEL CONTROL.

Figure 68. Schematic — 202J RF Unit

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